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THE SCIENTIFIC MONTHLY

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THE STATE OF SCIENCE IN 1924[1]

THE ELECTRON

By SIR J. J. THOMSON, O.M., F.R.S.

Electrons are particles of exceedingly small mass carrying a charge of negative electricity; there is only one kind of electron, for all electrons have the same mass and carry the same electric charge. Until the discovery in 1897 of the electron, the smallest mass known to science was that of an atom of the lightest element hydrogen, but the mass of this atom is 1,800 times greater than that of an electron. The mass of an electron is by far the smallest of all known masses. The electrons are the bricks which build up the atom; an atom of hydrogen contains one electron, an atom of oxygen eight, one of lead about one hundred, and so on. Differences in the number and arrangements of the electrons in the atom are supposed to account for the difference in the properties of the atoms of the different chemical elements.

Although the electron is by far the commonest and most widely distributed thing known, it was not discovered until 1897, and then in what may be called a highly specialized region. It had been shown by Plücker in 1859 that when an electric current passes through a gas at a low pressure the glass tube in which the gas is contained phosphoresces in the neighborhood of the cathode. The phosphorescence is due to something traveling in straight lines from the cathode, for if an obstacle such as a piece of glass rod is placed between the cathode and the walls of the tube a shadow of the obstacle is thrown on the wall. The nature of the "cathode rays," as the agents which produce this phosphorescence are called, was the subject of a long controversy. One view was that they arose from waves in the ether, another that they were due to negatively electrified particles. In support of the latter view were the facts that negative electricity

[1] Prepared for the Hand-book to the Exhibit of Pure Science, arranged by the Royal Society for the British Empire Exhibition.

traveled along the direction of the rays, and that the rays were deflected by a magnet; but against the view was the fact that the rays could pass through thin sheets of metal, such as gold foil. If these rays are electrified bodies, it is possible by certain methods to determine their mass, velocity and electric charge, and when this was done it was found that the carriers were not atoms or molecules, but something almost infinitesimal in comparison.

The mass and velocity of the electron were determined by measuring the deflections they experienced when acted on by electric and magnetic forces. Suppose the electron started off horizontally in a discharge tube. If it were not acted on by any forces it would strike the glass wall of the tube at a point opposite its starting point, and the place of impact would be marked by a patch of phosphorescence. If, however, it is acted on by a constant electric force X, acting vertically downwards, the electron would have a downward acceleration $\mathrm{X}e/m$ (if e is its electric charge and m its mass), and would fall just as a rifle bullet shot off horizontally would fall under gravity. The vertical fall of the bullet is $g \times l^2/2v^2$, where l is the horizontal distance passed over, v the velocity of projection, and g is the acceleration due to gravity. Putting $\mathrm{X}e/m$, the acceleration of the electron instead of g, we see that the distance fallen through by the electron will be $\mathrm{X}(e/m)l^2/2v^2$. Hence the electron acted on by the electric force will hit the glass at a point which is this distance below its original destination. If h is the deflection

$$h = \frac{\mathrm{X}}{2}\left(\frac{e}{mv^2}\right)l^2;$$

we can measure h, X, and l, and hence from this equation we can get e/mv^2.

If instead of acting on the electron by an electric force we act on it by a magnetic one, at right angles to the direction of motion, the force on the electron due to the magnet is $\mathrm{H}ev$; hence the acceleration is $\mathrm{H}ev/m$, and is at right angles to the path of the particle and in the direction of the magnetic force. Now suppose we let both the electric and magnetic forces act simultaneously, and let one act upwards and the other downwards. We can adjust the two forces until the accelerations due to them just balance, and the electron will then move as if neither electric nor magnetic force acted on it, and the phosphorescence will occur on the tube at the same point as that affected by the electron before either electric or magnetic force was introduced. For the acceleration to be equal

$$\frac{\mathrm{X}e}{m} = \frac{\mathrm{H}ev}{m} \quad \text{or} \quad v = \mathrm{X}/\mathrm{H}.$$

We can measure both X and H, and thus determine v. We have

previously determined e/mv^2, so that when we know v we can find e/m. This was found to be equal to 1.8×10^7.

Now if E is the charge of electricity carried by the hydrogen atom in the electrolysis of solutions, and M the mass of that atom, E/M can be determined by measuring the quantity of hydrogen liberated when a known quantity of electricity passes through an aqueous solution. This was done long ago, and the result was that $E/M = 10^4$. Special investigations have shown that e, the charge on the electron, is equal to E, the charge on the hydrogen ion; hence since $e = E$ and $e/m = 1.8 \times 10^7$, while $E/M = 10^4$, $m = M/1800$, or the mass of an electron is only 1/1800 of that of an atom of hydrogen.

Experiments were made on cathode rays produced with electrodes made of various metals and with different gases in the tube, but the mass of the electron and the charge of electricity it carried were found to be the same whatever might be the nature of the metal or the gas. The velocity of the rays, which was always very high—many thousand miles per second—varied with the potential difference between the electrodes. This high velocity makes the energy of an electron, in spite of its small mass, enormously greater than the energy of the ordinary molecules of a gas. Thus a comparatively slow electron, moving with a speed of 30,000 miles per second, has 250,000 times the average energy of a molecule of a gas at ordinary temperatures. It is this comparatively enormous energy which makes the detection and study of electrons easier than that of ordinary molecules.

When once electrons had been detected they were found to be very widely distributed. Thus it was found that they were given off by hot wires, and the hot-wire valves now so largely used in wireless telegraphy and for many other purposes work entirely by electrons; electrons are also given off by bodies when struck by ultra-violet light or by Röntgen rays. Radio-active bodies give off very high-speed electrons moving very nearly as fast as light. But whatever may be the means used to liberate them, or the source from which they come the electrons themselves are always found to be the same.

X-RAYS AND CRYSTAL STRUCTURE

By SIR WILLIAM BRAGG, F.R.S.

Diffraction of X-rays

There is a strong analogy between the use of X-rays in the investigation of crystal structure and the employment of light in conjunction with a diffraction grating. There is, however, a very great difference in scale, for the X-ray waves are ten thousand times

shorter than those of light. The ordinary diffraction grating consists of a sheet of metal or glass on which parallel lines are ruled, say, 20,000 to the inch. When a ray of homogeneous light is directed upon such a grating, diffracted pencils of light leave the grating in various directions according to well-known rules. That which is least diffracted we call the effect of the first order, and the others are of the second order, the third order and so on. The angles which these diffracted pencils make with the original rays are determined by two factors—namely, the wave-length of the light and the spacing of the lines on the grating, and it is possible, given a wave-length, to find the spacing by measuring the "angle of diffraction." Such a measurement is very exact. There is another well-known grating effect which is sometimes made use of. The relative intensities of the different orders, but not their angles of diffraction, depend upon the dimensions and form of the groove which the ruling diamond makes on the plate. Sometimes one spectrum is intensified by some particular characteristic in the forms of the grooves. It might be possible to work back from observations of the relative intensities to a determination of the shape of the groove.

When we turn to X-rays we find the analogue of the light waves in the waves of the X-rays and the analogue of the grating in the ordered arrangement of the crystal. If X-rays are allowed to fall upon a crystal, diffracted pencils may be emitted, and the angle which the diffracted pencil makes with the original ray depends upon the wave length of the X-rays and the spacings of the crystal. So far the diffraction of X-rays resembles the diffraction of light by a grating. There is, however, an additional effect in that the direction of the original rays has to be related to the lie of the crystal planes in different ways before any diffraction takes place at all. In the actual experiment the crystal is rotated about some important axis until the diffracted pencil of the rays flashes out and the angle of diffraction is then observed just as in the case of light.

The Units in the Structure of Crystals

The chemical molecule consists of a certain number of atoms arranged in an ordered way. When the molecules are built into a crystal they tend to an arrangement which has a higher symmetry than the molecule itself possesses. We may say that Nature puts together two, three, four or even more molecules in such a way as to make for higher symmetry. In this way she makes a unit of pattern. The units of pattern are distributed on the lines and plans of a lattice, each unit having exactly the same form, composition and outlook as every other unit; the whole structure of the crystal is an

orderly arrangement of these units. They may be considered to lie on various planes or sheets within the crystal just as the rows of trees in an orchard may be considered to lie in various rows, and each sheet corresponds to a line in the light-grating. The X-rays give the distance between sheet and sheet. They may do this for sheets drawn in various ways, and hence it is possible to determine the arrangement of the units in the crystal—that is to say, the form and dimensions of the cell occupied by one unit. This measurement corresponds to the determination of the spacing between two lines in the diffraction grating.

A further step which the X-rays can take is the determination of the relative intensities of the various orders of the diffracted rays. This information leads, if it can be interpreted, to a knowledge of the mutual arrangement of the molecules in the crystal. The operation which is always carried out in the case of X-rays so far as present experience will allow, is analogous to a determination of the form of the grooves of the diffraction grating by measuring the relative intensities of the various orders of diffracted light. Two stages may be distinguished in this process. One of them comparatively easy; the other of difficulty, and sometimes of very great difficulty.

The outer form of a crystal depends upon the internal arrangement of the atoms and molecules, and the group employed by Nature is in general the chemical molecule. It is possible to distinguish thirty-two different classes, each characterized by its own special form. Mathematical crystallography has carried the possibilities of classification further than the outward form can reveal. Taking any group of atoms, it has been shown that in each class having its special external characteristics, there are several ways of arranging the groups so as to give the same outward appearance. These different methods of arrangement are nearly always distinguishable from one another by their action on the X-rays. There are in all 230 of them. An early result of the X-ray analysis is, therefore, the determination of the special arrangement of the molecules within the crystal.

The next stage, the more difficult one, is a determination of the full linear and angular relations between the position of the molecules and the atoms within the molecules. The aids to this determination are relative measurements of intensities of diffraction as revealed by X-rays, to which must be added all that may be known of the chemical, physical and mechanical characteristics of the atoms and the molecules. In some simple cases the analysis may be said to be already complete, but in the hundreds of thousands of known crystals there is, of course, an immense field still to be covered.

Models can be constructed, based on the results already obtained, which illustrate the structure of many crystalline substances.

Interpretation of Crystal Structure

It will now be convenient to refer to some of the principles of structure which X-ray analysis has already revealed. It is clear that such principles are worthy of careful investigation, for they may throw light on chemical and physical actions and also help in further determinations of crystal structure. There is in the first place a broad division into different methods of combination between the atoms. Three types can be recognized. The first of these is illustrated by such crystal structures as rock-salt, fluorspar, calcite and so forth. The structure depends mainly upon a group formed in obedience to laws of electrostatic action. If, for example, we take the case of rock-salt, the chlorine atom has taken away from the sodium atom one electron which it has incorporated into its own structure. According to the modern views of atomic constitution the chlorine atom, which has seven electrons in its outermost electron shell, is eager to complete the shell—completion implying the presence of eight electrons in that shell. Neon, which has eight, already seems to show by its unwillingness to enter into chemical combination, in other words, by its unwillingness to give, take or share electrons, that there is something which makes the eight a satisfactory and complete number. Sodium has the completed outer shell of eight and one which is the beginning of a new shell external to the old. It appears to have a poor hold on this odd electron, so that chlorine easily removes it. In consequence the chlorine becomes a negatively charged body, and the sodium a positively charged body.

Each positive surrounds itself with as many negatives as possible, and each negative with as many positives as possible. The cubic structure of rock-salt is obtained in this way, each atom having six neighbors of opposite sign. In fluorspar, where the calcium atom has been robbed of its two extra electrons by two fluorine atoms, each of which takes one, Nature has found a structure in which the positively charged calcium is surrounded by eight negative fluorines, and the fluorines by four calciums. In Iceland spar the same principle governs the structure. Each calcium atom is surrounded by six CO_3 groups, and each CO_3 group by six calciums. The structure is not, however, so regular as a rock-salt because the CO_3 group is not spherical in form and characteristic. There is a large class of crystals built on the same plan. There is a certain indefiniteness about the molecule because a positive can be associated with any one of the six negative neighbors which it possesses. It is

notable that, in the calcite, the CO_3 group must have such a degree of symmetry as is represented by the properties of an equilateral triangle. If it is turned round 120° in its own plane, it has the same appearance as before. This implies that the three oxygen atoms are all alike in their relations to one another, and to the other atoms of the crystal. However, the crystal may come to pieces under chemical action. A compound of calcium atoms and CO_3 groups is not a mixture of CO_2 and CaO. It is supposed that the carbon atom is stripped of all the four electrons which it normally possesses in its outer shell. The calcium atom loses also the two electrons which it has outside its completed shell. Each of the oxygen atoms takes two of the six electrons thus set free. Consequently each carbon atom has a quadruple positive charge, each oxygen a double negative charge, and the calcium a double positive charge.

A second method of combination is to be found in the diamond. The carbon atoms of which alone it consists are so arranged that each carbon has four neighbors arranged about it in tetrahedral fashion. Each shares two electrons with each of its neighbors, and in this way covers itself with the desired shell of eight electrons. It appears that the sharing produces a very strong bonding; the diamond is the hardest of known substances.

In graphite there are sheets of atoms tied tightly to one another by the sharing bonds of the diamond, but these sheets are separated from one another by a considerable interval. In this way may be explained the slipperiness of graphite and its usefulness as a lubricant because in the first place the layers slip on one another easily, the bonds that tie them together being weak, and in the second place, the atoms in each layer hold tightly together. There are indications that these tight bonds are much less affected by temperature than bonds of a looser type. For example, the coefficient of expansion with heat of the diamond is far less than the average expansion of graphite, but the expansion of graphite takes place almost entirely through increased separation of the layers.

Organic Crystals

There is yet a third method of combination, in general much weaker than the other two. When molecules, as in organic crystals, are built together into a structure, the forces that bind together molecule and molecule may be comparatively weak. The separate molecules are not positive or negative to each other, nor do they share electrons, but no doubt there are stray fields, perhaps electric, perhaps magnetic, at different points on their surfaces which cause the molecules to be joined on to one another like the girders of an iron bridge. The crystal structure is very empty; it is like lace-

work in space. We get the first hint of this likeness in the diamond where the empty spaces are big enough to accommodate as many more carbon atoms as a diamond already contains. The root principle seems to be that the carbon atom, when sharing electrons, gathers round it four neighbors more or less at the corners of a tetrahedron. If these points of attachment are spaced, so to speak, over the surface of the carbon atom, it is easy to understand how these open structures can be formed.

In the diamond crystal the structure shows two types of arrangement which form the basis of two of the great groups of organic substances. There is in the first place the hexagonal ring, which appears to be capable of separate existence in unchanged form and dimension, and when fringed with various atoms of radicles to form the innumerable members of the aromatic series. The double and treble rings are found in naphthalene and anthracene respectively, and the structure of these crystals, as revealed by X-rays, shows that the ring is the same in all respects as in the diamond. There is also to be found in the diamond an arrangement of long chains, which may have any length of carbon atoms. These chains, when fringed along their length by hydrogen atoms and finished off at each end with various groups of atoms, such as the methyl group (CH_3), the carboxyl group (COOH), the hydroxyl group (OH), and so on, form the well-known chain compounds of organic chemistry. Measurements of the lengths of these chains have recently been made very exactly by the X-ray methods in a number of cases, and it appears that the arrangement is, as the models show, just the same as is found in the diamond. The essential feature is that any two carbon atoms are joined on to a third at points on the surface of the latter, which are tetrahedral points.

Structure of Metals

The application of the X-rays to the crystal analysis of metals has shown very remarkable results, which will probably receive great extension in the future. Many of the metals—aluminium, silver, copper and gold, for example—are of a structure which implies the simplest form of close packing of spherical atoms. These plates are those in which the packing is most dense. A mass of crystals is stronger than a single crystal because the planes of weakness lie in all directions. An admixture of a certain number of foreign atoms causes a distortion of the structure, which diminishes the possibility of slip, and thus the hardening effect of an alloid is explained.

In the case of steel it seems likely that the carbon atoms do not replace iron atoms, as for example, tin atoms replace those of copper

in the formation of bronze; they appear to fit into the interstices of the structure. The structural nature of the various crystals which form in alloys, as for example, cementite in steel and intermetallic compounds in other alloys, have also been the subject of investigation.

Among the many other developments to which X-ray analysis is leading, one more may be mentioned. It now seems possible to calculate, from a knowledge of the structure and of the atoms which compose it, the effects upon electro-magnetic waves, such as those of light on their way through the crystal. A beginning in this respect has been made with the measurements of the reflection indices of calcite and aragonite.

ELECTRICITY AND MATTER[1]

By SIR ERNEST RUTHERFORD, F.R.S.

The Electron

The discovery by Sir J. J. Thomson in 1897 of the individual existence of the negative electron of small mass, and the proof that it was a component of all the atoms of matter, was an event of extraordinary significance to science, not only for the light which it threw on the nature of electricity, but also for the promise it gave of methods of direct attack on the problem of the structure of the atom. This discovery of the electron, coupled with the recognition of the atomic nature of electricity, has created a veritable revolution in our ideas of atoms.

It was soon recognized that the negative electron of small mass was an actual disembodied atom of electricity, and that its apparent mass was electrical in origin. Sir J. J. Thomson had shown so early as 1881 that a charged body in motion behaved as if it had an additional electric mass due to its motion. The moving charge generates a magnetic field in the space surrounding it, resulting in an increase of energy of the moving system which is equivalent to the effect produced by an increase of the mass of the body.

Since there must always be electric mass associated with the movement of electric charges, it is natural to suppose that the mass of the electron is entirely electrical in origin, and no advantage is gained by supposing that any other type of mass exists. If the atom is a purely electrical structure, the mass of the atom itself must be due to the resultant of the electric mass of the charged particles

[1] Abstracted from the Kelvin Lecture delivered before the Institution of Electrical Engineers on May 18, 1922.

which make up its structure. As only a small fraction of the mass of an atom can be ascribed to the negative electrons contained in it, the main part is due to the positively charged units of its structure.

The Proton

One of the main difficulties in our attack on the question of atomic constitution has lain in the uncertainty of the nature of positive electricity. The evidence as a whole supports the idea that the nucleus of the hydrogen atom, *i.e.*, a positively charged atom of hydrogen, is the positive electron. No evidence has been obtained of the existence of a positively charged unit of mass less than that of the hydrogen nucleus, either in vacuum tubes or in the transformation of the radio-active atoms, where the processes occurring are very fundamental in character.

It might *a priori* have been anticipated that the positive electron should be the counterpart of the negative electron and have the same small mass. There is, however, not the slightest evidence of the existence of such a counterpart. On the views outlined, the positive and negative electrons both consist of the fundamental unit of charge, but the mass of the positive is about 1,800 times that of the negative. This difference in the mass of the two electrons seems a fundamental fact of Nature, and, indeed, is essential for the existence of atoms as we know them. The unsymmetrical distribution of positive and negative electricity that is characteristic of all atoms is a consequence of this wide difference in the mass of the ultimate electrons which compose their structure. No explanation can be offered at the moment why such a difference should exist between positive and negative electricity.

Since it may be argued that a positive unit of electricity associated with a much smaller mass than the hydrogen nucleus may yet be discovered, it may be desirable not to prejudge the question by calling the hydrogen nucleus the positive electron. For this reason, and also for brevity, it has been proposed that the name "proton" should be given to the unit of positive electricity associated in the free state with a mass about that of the hydrogen nucleus. In the following, the term "electron" will be applied only to the well-known negative unit of electricity of small mass.

On the classical electrical theory, the mass of the electron can be accounted for by supposing that the negative electricity is distributed on a spherical surface of radius about 1×10^{-13} cm. This is merely an estimate, but probably gives the right order of magnitude of the dimensions.

The greater mass of the proton is to be explained by supposing that the distribution of electricity is much more concentrated for

the proton than for the electron. Supposing the shape spherical, the radius of the proton should be only 1/1800 of that of the electron. If this be so, the proton has the smallest dimensions of any particle known to us. It is admittedly very difficult to give any convincing proof in support of this contention, but at the same time there is no evidence against it.

Structure of the Atom

Progress in the last twenty years of our ideas on the structure of atoms has depended mainly on a clearer understanding of the relative part played by positive and negative electricity in atomic structure. It is now generally accepted that the atom is an electrical system and that the atoms of all the elements have a similar type of structure.

The nuclear theory of atomic constitution has been found to be of extraordinary value in offering an explanation of the fundamental facts that have come to light, and is now generally employed in all detailed theories of atomic constitution. At the center of each atom is a massive positively charged nucleus of dimensions minute compared with the diameter of the atom. This nucleus is surrounded by distribution of negative electrons which extend to a distance, and occupy rather than fill a region of diameter about 2×10^{-8} cm. Apart from the mass of the atom, which resides mainly in the nucleus, the number and distribution of the outer electrons, on which the ordinary physical and chemical properties of the atom depend, are controlled by the magnitude of the nuclear charge. The position and motions of the external electrons are only slightly affected by the mass of the nucleus.

According to this view of the atom, the problem of its constitution naturally falls into two parts—first, the distribution and mode of motion of the outer electrons, and secondly, the structure of the nucleus and the magnitude of the resultant positive charge carried by it. In a neutral atom the number of external electrons is obviously equal in number to the units of positive (resultant) charge on the nucleus.

The general conception of the nuclear atom arose from the need of explanation of the very large deflexions experienced by swift particles thrown off by radio-active substances, known as α- and β-particles, in passing through the atoms of matter. A study of the number of α-particles scattered through different angles showed that there must be a very intense electric field within the atom, and gave us a method of estimating the magnitude of the charge on the nucleus. Similarly, the scattering of X-rays by the outer electrons provided us with an estimate of the number of these electrons in the

atom, and the two methods gave concordant values. The next great advance we owe to the experiments of Moseley on the X-ray spectra of the elements. He showed that his experiments received a simple explanation if the nuclear charge varied by one unit in passing from one atom to the next. In addition, it was deduced that the actual magnitude of the nuclear charge of an atom in fundamental units is equal to the atomic or ordinal number when the elements were arranged in order of increasing atomic weight. On this view, the nuclear charge of hydrogen is 1, of helium 2, lithium 3, and so on up to the heaviest element uranium, of charge 92. It has been found that between these limits, with few exceptions, all nuclear charges are represented by known elements.

This relation, found by Moseley, between the atoms of the elements, is of unexpected simplicity and of extraordinary interest. The properties of an atom are defined by a whole number which varies by unity in passing from one atom to the next. This *atomic number* represents not only the ordinal number of the elements, but also the magnitude of the charge of the nucleus and the number of outer electrons. The atomic weight of an element is not nearly so fundamental a property of the atom as its nuclear charge, for its weight depends upon the inner structure of the nucleus, which may be different for atoms of the same nuclear charge.

The Nucleus of the Atom

The most definite information we have of the structure of the nucleus of an atom has been obtained from a study of the modes of disintegration of the radio-active atoms. In the great majority of cases the atom breaks up with the expulsion of a single α-particle which represents the doubly charged nucleus of the helium atom; in other cases a swift β-ray or electron is liberated. There can be no doubt that these particles are liberated from the nuclei of the radio-active atoms. This is clearly shown by the variation of the atomic numbers (the figures enclosed by the circles) of the successive elements in the long series of transformations of uranium and thorium (see Fig. 1). The expulsion of an α-particle lowers the nuclear *charge* of the atom by two units and its *mass* by four, while the expulsion of an electron raises its charge by one. On this simple basis we can at once deduce the atomic number and, consequently, the general chemical properties of the long series of radio-active elements. In this way we can understand at once the appearance in the radio-active series of isotopes, *i.e.*, elements of the same nuclear charge but different atomic masses.

The existence of isotopic elements was first brought to light from

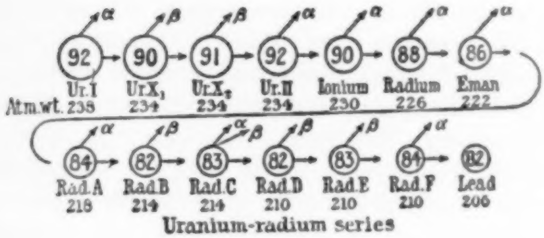

FIG. 1

a study of the radio-active elements. For example, radium-*B*, radium-*D* and the end product, uranium-lead, are isotopes of lead of nuclear charge 82, but of masses 214, 210 and 206 respectively. As regards ordinary chemical and physical properties, they are indistinguishable from one another, differing only in properties that depend on the nucleus, namely, atomic mass and radio-activity. For example, radium-*B* and radium-*D* both emit β-rays, but with different velocities, while their average life is widely different. Uranium-lead, on the other hand, is non-radio-active. Many similar examples can be taken from the thorium and actinium series of elements. These illustrations show clearly that elements may have almost identical physical and chemical properties, and yet differ markedly in the mass and structure of their nuclei.

From the radio-active evidence, it seems clear that the nuclear structure contains both helium nuclei and electrons. In the uranium-radium series of transformations, eight helium nuclei are emitted and six electrons, and it is natural to suppose that the helium nuclei and electrons that are ejected act as units of the nuclear structure. It is clear from these results that the nuclear charge of an element is the excess of the positive charges in the nucleus over the negative. It is a striking fact that no protons (H nuclei) appear to be emitted in any of the radio-active transformations, but only helium nuclei and electrons.

Some very definite and important information on the structure of nuclei has been obtained by Aston in his experiments to show the existence of isotopes in the ordinary stable elements by the well-known positive-ray method. He found that a number of the elements were simple and contained no isotopes. Examples of such "pure" elements are carbon, nitrogen, oxygen and fluorine. It is significant that the atomic weights of these elements are nearly whole numbers in terms of $O=16$; on the other hand, elements such as neon, chlorine, krypton and many others consisted of mixtures of two or more isotopes of different atomic masses. Aston

found that within the limit of error—about 1 in 1,000—the atomic weights of these isotopes were whole numbers on the oxygen scale. This is a very important result, and suggests that the nuclei of elements are built up by the addition of protons, of mass nearly one, in the nuclear combination.

Disintegration of Elements

There seems to be no doubt that the nucleus of an atom is held together by very powerful forces, and that we can only hope to effect its disintegration by very concentrated sources of energy applied directly to the nucleus. The most concentrated source of energy known to us is the swift α-particle expelled from radium or thorium. It is liberated with a velocity of 10,000 miles per second, and has so much energy that it produces an easily visible flash on striking a zinc sulphide crystal. Its speed is twenty thousand times greater than that of a swift rifle bullet, and, mass for mass, its energy of motion is four hundred million times greater than that of the bullet.

A stream of α-particles is therefore made to bombard the atoms of the material under examination. On account of the minute size of the nucleus, we can expect an α-particle only occasionally to get near enough to the nucleus to effect its disintegration, and this method should be more likely to succeed with a light atom, in which the repulsive force of the nucleus would not be so great as that of a heavy atom with high nuclear charge.

The first observation indicating the disruption of the nitrogen nucleus was made some years ago. When α-particles were passed through oxygen or carbon-dioxide, a few particles of long range were observed. These appeared to be H-nuclei set free from hydrogen in the radio-active source, which, on account of their small mass, would be expected to have a greater range than the α-particles liberating them. When, however, dry air or nitrogen is submitted to such a bombardment, the number of long-range particles is three or four times as numerous, and they have a greater average range. These behaved in all respects as H-nuclei, and it was concluded that they arose from disruption of the nitrogen nuclei.

Using improved apparatus, it was possible to show that similar long-range particles were liberated from boron, fluorine, sodium, aluminium and phosphorus. The range of the particles is in all cases greater than that of the H-particles liberated from free H atoms under similar conditions. For example, using radium-*C* as a source of X-rays, the range of the H-nuclei is about 28 cm. Under similar conditions, the range of the particles from nitrogen is 40

cm., while the range of particles from aluminium is as much as 90 cm.

It is thus natural to conclude that "protons" have been ejected from the nuclei of certain light elements by the action of the α-particles. It is significant that no protons are liberated from carbon (12) and oxygen (16), the atomic weights of which are given by $4n$, where n is a whole number. Protons are only observed from elements of which the atomic weights are expressed by $4n + a$, where a is 2 or 3. These results suggest that the elements are, in the main, built up of helium nuclei of mass 4, and protons. The α-particle is unable to liberate a proton from elements like carbon and oxygen which are built up entirely of helium nuclei as secondary units, probably because the helium nucleus is too stable to be broken up by the swiftest α-particle available. It should be borne in mind, however, that this disintegration phenomenon effected by α-particles is on an exceedingly minute scale. Only two protons are liberated from aluminium for a million α-particles traversing it.

The Architecture of Atoms

From the radio-active evidence, we know that the nuclei of heavy atoms are built up, in part at least, of helium nuclei and electrons, while it also seems clear that the proton can be released from the nuclei of certain light atoms. It is, however, very natural to suppose that the helium nucleus which carries two positive charges is a secondary building unit, composed of a close combination of protons and electrons, namely, 4 protons and 2 electrons.

From the point of view of simplicity, such a conception has much in its favor, although it seems at the moment impossible to prove its correctness. If, however, we take this structure of the helium nucleus as a working hypothesis, certain very important consequences follow.

Taking the mass of the oxygen atom as 16 (the standard which is usually adopted in atomic weight determinations), the helium atom has a mass very nearly 4·000, while the hydrogen atom has a mass 1·0077. The mass of the helium atom is thus considerably less than that of four free H-nuclei. Disregarding the small mass of electrons, in the formation of 1 gram of helium from hydrogen there would be a loss of mass of 7·7 milligrams.

It is now generally accepted that if the formation of a complex system is accompanied by the radiation of energy, a reduction of its mass occurs, which can be calculated. In the formation of 1 gram of helium from hydrogen an enormous amount of energy is set free; the energy radiated in forming one single atom of helium is equivalent to the energy carried by three or four swift α-particles from

radium. On this view we can at once understand why it should be impossible to break up the helium nucleus by a collision with an α-particle. In fact, the helium atom should be by far the most stable of all the complex atoms.

Most workers on the problem of atomic constitution take as a working hypothesis that the atoms of matter are purely electrical structures, and that ultimately it is hoped to explain all the properties of atoms as a result of certain combinations of the two fundamental units of positive and negative electricity, the proton and electron. Some of the more successful methods of attack that have been made on this most difficult of problems have been indicated. During recent years unexpectedly rapid advances have been made in our knowledge, but we have only made a beginning in the attack on a very great and intricate problem.

ATOMS AND ISOTOPES[1]

By Dr. F. W. ASTON, F.R.S.

The Size of Atoms

That matter is discontinuous and consists of discrete particles is by no means obvious to the senses. The surfaces of clean liquids, even under the most powerful microscope, appear perfectly smooth, coherent and continuous. The merest trace of a soluble dye will color millions of times its volume of water. It is not surprising therefore that, in the past, there have arisen schools who believed that matter was quite continuous and infinitely divisible.

The upholders of this view said that if you took a piece of material, lead, for instance, and went on cutting it into smaller and smaller fragments with a sufficiently sharp knife, you could go on indefinitely. The opposing school argued that at some stage in the operations either the act of section would become impossible, or the result would be lead no longer.

The accuracy of modern knowledge is such that we can carry out, indirectly at least, the experiment suggested by the old philosophers right up to the stage when the second school is proved correct, and the ultimate atom of lead is reached. For convenience, we can start with a standard decimeter cube of lead weighing 11.37 kilograms, and the operation of section will consist of three cuts at right angles to each other, dividing the original cube into eight similar bodies, each of half the linear dimensions and one eighth the weight.

[1] Abstracted from lecture delivered before the Franklin Institute, Philadelphia, on March 6–10, 1922.

Thus the first cube will have 5 cm. sides and weigh 1·42 kilograms, the second will weigh 1·78 gm., the fourth 2·78 gm., and so on. Diminution in the series is very rapid, and the result of the ninth operation is a quantity of lead just weighable on the ordinary chemical balance. The last operation possible, without breaking up the lead atom, is the twenty-eighth. The twenty-sixth cube contains 64 atoms, the size, distance apart and general arrangement of which can be represented with considerable accuracy, thanks to the exact knowledge derived from research on X-rays and specific heats.

The following table shows at what stages certain analytical methods break down. The great superiority of the microscope is a noteworthy point.

Cube.	Side in cm.	Mass in gm.	Limiting Analytical Method.
9	0.0195	8.5×10^{-5}	Ordinary Chemical Balance.
14	6.1×10^{-4}	2.58×10^{-9}	Quartz Micro-balance.
15	3.05×10^{-4}	3.22×10^{-10}	Spectrum Analysis (Na lines).
18	3.8×10^{-5}	6.25×10^{-13}	Ordinary Microscope.
24	6.0×10^{-7}	2.38×10^{-18}	Ultra-Microscope.
28	3.7×10^{-8}	5.15×10^{-22}	
Atom	3.0×10^{-8}	3.44×10^{-22}	Radioactivity.

Just as any vivid notion of the size of the cubes passes out of our power at about the twelfth—the limiting size of a dark object visible to the unaided eye—so when one considers the figures expressing the number of atoms in any ordinary mass of material, the mind is staggered by their immensity. Thus if we slice the original decimeter cube into square plates one atom thick, the area of these plates will total one and one quarter square miles. If we cut these plates into strings of atoms spaced apart as they are in the solid, these decimeter strings put end-to-end will reach 6.3 million million miles, the distance light will travel in a year, a quarter of the distance to the nearest fixed star. If the atoms are spaced but one millimeter apart, the string will be three and a half million times longer yet, spanning the whole universe.

From the above statements it would, at first sight, appear absurd to hope to obtain effects from single atoms, yet this can now be done in several ways, and indeed it is largely due to the results of such experiments that the figures can be stated with so much confidence. Detection of an individual is only feasible in the case of an atom moving with an enormous velocity, when its energy is quite appreciable, although its mass is so minute. The charged helium atom shot out by radioactive substances in the form of an α-ray possesses so much energy that the splash of light caused by its impact against a fluorescent screen can be visibly detected; the ionization caused by its passage through a suitable gas can be measured on a sensitive

electrometer, and, in the beautiful experiments of C. T. R. Wilson, its path in air can be both seen and photographed by means of the condensation of water drops upon the atomic wreckage it leaves behind it.

Discovery of Isotopes

In the first complete atomic theory put forward by Dalton in 1803 one of the postulates states that: "Atoms of the same element are similar to one another and equal in weight." Of course, if we take this as a definition of the word "element" it becomes a truism, but, on the other hand, what Dalton probably meant by an element, and what we understand by the word to-day, is a substance such as hydrogen, oxygen, chlorine, or lead, which has unique chemical properties, and can not be resolved into more elementary constituents by any known chemical process. For many of the well-known elements Dalton's postulate still appears to be strictly true, but for others, probably the majority, it needs some modification.

The idea that atoms of the same element are all identical in weight could not be challenged by ordinary chemical methods, for the atoms are by definition chemically identical, and numerical ratios were only to be obtained in such methods by the use of quantities of the element containing countless myriads of atoms.

There are two ways by which the identity of the weights of the atoms forming an element can be tested. One is by the direct comparison of the weights of individual atoms; the other is by obtaining samples of the element from different sources or by different processes, samples which, although perfectly pure, do not give the same chemical atomic weight. It was by the second and less direct of these methods that it was first shown that substances could exist which, though chemically identical, had different atomic weights. To these the name "isotopes" was applied by Prof. Soddy.

Measurement of Masses of Individual Atoms

In the absence of the special radioactive evidence which can be used in special cases such as that of lead, the presence of isotopes among the inactive elements can only be detected by the direct measurement of the masses of individual atoms. This can be done by the analysis of positive rays.

The condition for the development of these rays is briefly ionization at low pressure in a strong electric field. Ionization, which may be due to collisions or radiation, means in its simplest case the detachment of one electron from a neutral atom. The two resulting fragments carry charges of electricity of equal quantity

but of opposite sign. The negatively-charged one is the electron, the atomic unit of negative electricity itself, and is the same whatever the atom ionized. It is extremely light, and therefore in the strong electric field rapidly attains a high velocity and becomes a cathode ray. The remaining fragment is clearly dependent on the nature of the atom ionized. It is immensely more massive than the electron, for the mass of the lightest atom, that of hydrogen, is about 1,800 times that of the electron, and so will attain a much lower velocity under the action of the electric field. However, if the field is strong and the pressure so low that it does not collide with other atoms too frequently, it will ultimately attain a high speed in a direction opposite to that of the detached electron, and become a "positive ray."

Positive rays can be formed from molecules as well as atoms; so any measurement of their mass will give us direct information as to the masses of atoms of elements and molecules of compounds; moreover, this information will refer to the atoms or molecules *individually*, not, as in chemistry, to the mean of an immense aggregate. It is on this account that the accurate analysis of positive rays is of such importance.

In order to investigate and analyze them it is necessary to obtain intense beams of the rays. This can be done in several ways. The one most generally available is by the use of the discharge in gases at low pressure.

The comparatively dimly lit space in a discharge tube between the cathode and the bright "negative glow" is named after its discoverer the "Crookes' dark space." Ionization is going on at all points throughout the dark space, and it reaches a very high intensity in the negative glow. This ionization is probably caused for the most part by electrons liberated from the surface of the cathode (cathode rays). These, when they reach a speed sufficient to ionize by collision, liberate more free electrons, which in their turn become ionizing agents, so that the intensity of ionization from this cause will tend to increase as we move away from the cathode. The liberation of the original electrons from the surface of the cathode is generally regarded as due to the impact of the positive ions (positive rays) generated in the negative glow and the dark space. In addition to cathode ray ionization the positive rays travelling towards the cathode themselves are capable of ionizing the gas, and radiation may also play an important part in the same process.

The surface of the cathode will therefore be under a continuous hail of positively charged particles. Their masses may be expected to vary from that of the lightest atom to that of the heaviest mol-

ecule capable of existence in the discharge tube, and their energies from an indefinitely small value to a maximum expressed by the product of the charge they carry multiplied by the total potential applied to the electrodes. If the cathode be pierced, the rays pass through the aperture and form a stream, heterogeneous both in mass and velocity, which can be subjected to examination and analysis.

Analysis of Positive Rays

In Sir J. J. Thomson's "parabola" method of analysis of positive rays, the particles, after reaching the surface of the cathode, enter a long and very fine metal tube. By this means a narrow beam of rays is produced which is passed through electric and magnetic fields, causing deflexions at right angles to each other, and finally falls upon a screen of fluorescent material or a photographic plate. It can then be shown that if the mass of any particle is m and its charge e, when both fields are on together, the locus of impact of all particles of the same e/m, but varying velocity, will be a parabola. Since e must be the electronic charge, or a simple multiple of it, measurement of the relative positions of the parabolas on the plate enables us to calculate the relative masses of the particles producing them—that is, the masses of the individual atoms. The fact that the streaks were definite, sharp parabolas, and not mere blurs, constituted the first direct proof that atoms of the same element were, even approximately, of equal mass.

Many gases were examined by this method, and some remarkable compounds, such as H_3, discovered by its means. When in 1912 neon was introduced into the discharge tube, it was observed to exhibit an interesting peculiarity. Whereas all elements previously examined gave single, or apparently single, parabolas, that given by neon was definitely double. The brighter curve corresponded roughly to an atomic weight of 20, the fainter companion to one of 22, the atomic weight of neon being 20.20. Sir J. J. Thomson was of the opinion that line 22 could not be attributed to any compound, but that it represented a hitherto unknown elementary constituent of neon. This agreed very well with the idea of isotopes which had just been promulgated, so that it was of great importance to investigate the point as fully as possible.

The first line of attack was an attempt at separation by fractional distillation over charcoal cooled with liquid air, but even after many thousands of operations the result was entirely negative. The second method employed was that of fractional diffusion through pipeclay, which after months of arduous work gave a small,

but definite positive indication of separation. A difference of about 0.7 per cent. between the densities of the heaviest and lightest fractions was obtained. It therefore seemed probable that neon was a mixture of isotopes.

The Mass-Spectrograph

By the time the work on the subject was resumed in 1919, the existence of isotopes among the products of radio-activity had been put beyond all reasonable doubt by the work on the atomic weight of lead. This fact automatically increased both the value of the evidence of the complex nature of neon and the urgency of its definite confirmation. It was realized that separation could only be very partial at the best, and that the most satisfactory proof would be afforded by measurements of atomic weight by the method of positive rays. These would have to be so accurate as to prove beyond dispute that the accepted atomic weight lay between the real atomic weights of the constituents, but corresponded with neither of them.

The parabola method of analysis was not sufficient for this, but the required accuracy was achieved by a new arrangement. The rays, after arriving at the cathode face, are made to pass through two very narrow parallel slits of special construction, and the resulting thin ribbon of rays is spread out into an electric spectrum by means of parallel charged plates. After emerging from the electric field, a group of the rays is selected by means of a diaphragm, and made to pass between the parallel poles of a magnet. By this means the rays are brought to a focus, though spread out spectrum fashion, on a photographic plate.

Thus the instrument is a close analogue of the ordinary spectrograph, and gives a "spectrum," which, however, depends upon mass; it was therefore called a "mass-spectrograph" and the spectrum it produces a "mass-spectrum."

The measurements of mass thus made are not absolute, but relative to lines which correspond to known masses. Such lines due to hydrogen, carbon, oxygen and their compounds are generally present as impurities or purposely added, for pure gases are not suitable for the smooth working of the discharge tube.

It must be remembered that the ratio of mass to charge is the real quantity measured by the position of the lines. Many of the particles are capable of carrying more than one charge. A particle carrying two charges will appear as having half its real mass, one carrying three charges as if its mass was one third, and so on. Lines due to these are called lines of the second and third order.

Lines of high order are particularly valuable in extending the reference scale.

When neon was introduced into the apparatus, four new lines made their appearance at 10, 11, 20 and 22. The first pair are second order lines and are fainter than the other two, and a series of consistent measurements showed that to within about one part in a thousand the atomic weights of the isotopes composing neon are 20 and 22 respectively. Ten per cent. of the latter would bring the mean atomic weight to the accepted value of 20.20, and the relative intensity of the lines agrees well with this proportion. The isotopic constitution of neon seems therefore settled beyond all doubt.

The element chlorine was naturally the next to be analyzed, and the explanation of its fractional atomic weight was obvious from the first plate taken. Its mass spectrum is characterized by four strong first order lines at 35, 36, 37, 38, with fainter ones at 39, 40. There is no sign whatever of any line at 35·46. The simplest explanation of the group is to suppose that the lines 35 and 37 are due to the isotopic chlorines and lines 36 and 38 to their corresponding hydrochloric acids. The elementary nature of lines 35 and 37 is also indicated by the second order lines at 17.5, 18.5, and also, when phosgene was used, by the appearance of lines at 63, 65, due to $COCl^{35}$ and $COCl^{37}$.

Quite recently it has been found possible to obtain the spectrum of negatively-charged rays. These rays are formed by a normal positively-charged ray picking up two electrons. On the negative spectrum of chlorine only two lines, 35 and 37, can be seen, so that the lines at 36 and 38 can not be due to isotopes of the element. These results go to show that chlorine is a complex element, and that its principal isotopes are of atomic weight 35 and 37. There may be, in addition, a small proportion of a third of weight, 39, but this is doubtful.

The method of positive ray analysis having been applied so successfully to neon and chlorine, other elements were quickly submitted to its searching investigation. Positive rays of the metallic elements can not, in general, be obtained by the discharge tube method, but require special devices. Thus the isotopic nature of lithium was first demonstrated by the use of anode rays derived from anodes containing salts of that metal, and since then, all the other alkali metals have been successfully analyzed.

A powerful and ingenious method of generating positive rays of metallic elements has been used with great success by Dempster at Chicago. He employs the element in the metallic state, and

ionizes its vapor by means of a subsidiary beam of cathode rays. The ions so produced are allowed to fall through a definite potential, and, being therefore of constant energy, can be analyzed by the use of a magnetic field alone. By this arrangement Dempster discovered the three isotopes of magnesium, and has since analyzed other metals. Since the majority of the elements not yet investigated are metals, Dempster's method is likely to yield enormously important results in the future. A complete list of the isotopes of the non-radio-active elements so far discovered is given in the table.

TABLE OF ELEMENTS AND ISOTOPES

Element	Atomic number	Atomic weight	Minimum number of isotopes	Masses of isotopes in order of intensity
H	1	1.008	1	1.008
He	2	3.99	1	4
Li	3	6.94	2	7, 6
Be	4	9.1	1	9
B	5	10.9	2	11, 10
C	6	12.00	1	12
N	7	14.01	1	14
O	8	16.00	1	16
F	9	19.00	1	19
Ne	10	20.20	2	20, 22
Na	11	23.00	1	23
Mg	12	24.32	3	24, 25, 26
Al	13	26.96	1	27
Si	14	28.3	2	28, 29, (30)
P	15	31.04	1	31
S	16	32.06	1	32
Cl	17	35.46	2	35, 37
A	18	39.88	2	40, 36
K	19	39.10	2	39, 41
Ca	20	40.07	(2)	40, 44
Sc	21	45.1	1	45
Ti	22	48.1	1	48
V	23	51.0	1	51
Cr	24	52.0	1	52
Mn	25	54.93	1	55
Fe	26	55.84	(1)	56, (54) ?
Co	27	58.97	1	59
Ni	28	58.68	2	58, 60
Cu	29	63.57	2	63, 65
Zn	30	65.37	(4)	64, 66, 68, 70
Ga	31	69.72	2	69, 71
Ge	32	72.5	3	74, 72, 70
As	33	74.96	1	75
Se	34	79.2	6	80, 78, 76, 82, 77, 74
Br	35	79.92	2	79, 81
Kr	36	82.92	6	84, 86, 82, 83, 80, 78
Rb	37	85.45	2	85, 87
Sr	38	87.63	1	88
Y	39	88.9	1	89
Ag	47	107.88	2	107, 109
In	49	114.8	1	115
Sn	50	118.7	7 (8)	120, 118, 116, 124, 119, 117, 122, (121)
Sb	51	121.77	2	121, 123
I	53	126.92	1	127
X	54	130.2	7 (9)	129, 132, 131, 134, 136, 128, 130, (126), (124)
Cs	55	132.81	1	133
Hg	80	200.6	(6)	(197–200), 202, 204

(Numbers in parentheses are provisional only.)

SIGNIFICANCE OF THE DISCOVERY OF ISOTOPES

By far the most important general result of these investigations is that, with the exception of hydrogen, the weights of the atoms of all the elements measured, and therefore almost certainly of all elements, are whole numbers to the accuracy of experiment. With the mass-spectrograph, this accuracy is generally one part in a thousand. Of course, the error expressed in fractions of a unit in-

creases with the weight measured, but with the lighter elements the divergence from the whole number rule is extremely small.

This enables the most sweeping simplifications to be made in our ideas of mass. The original hypothesis of Prout, put forward in 1815, that all atoms were themselves built of atoms of "protyle," a hypothetical element which he tried to identify with hydrogen, is now re-established, with the modification that the primordial atoms are of two kinds: Protons and electrons, the atoms of positive and negative electricity. The atom, as conceived by Sir Ernest Rutherford, consists essentially of a positively-charged central nucleus around which are set planetary electrons at distances great compared with the dimensions of the nucleus itself.

The chemical properties of an element depend solely on its atomic number, which is the charge on its nucleus expressed in terms of the unit charge, e. A neutral atom of an element of atomic number N has a nucleus consisting of $K + N$ protons and K electrons and around this nucleus are set N electrons. The weight of an electron on the scale we are using is 0.0005, so that it may be neglected. The weight of this atom will therefore be $K + N$, so that if no restrictions are placed on the value of K, any number of isotopes are possible.

A statistical study of the results given above shows that the natural restrictions can be stated in the form of rules as follows:

(a) *In the Nucleus of an Atom There is Never Less Than One Electron to Every Two Protons.*—There is no known exception to this law. It is the expression of the fact that if an element has an atomic number N, the atomic weight of its lightest isotope can not be less than $2N$. True atomic weights corresponding exactly to $2N$ are known in the majority of the lighter elements up to A^{36}. Among the heavier elements the difference between the weight of the lightest isotope and the value $2N$ tends to increase with the atomic weight; in the cases of mercury it amounts to 37 units.

(b) *The Number of Isotopes of an Element and their Range of Atomic Weight Appear to Have Definite Limits.*—So far the element with the largest number of isotopes determined with certainty is krypton, with six, but the majority of complex elements have only two each. The maximum difference between the lightest and heaviest isotope of the same element so far determined is 8 units in the cases of krypton and xenon. The greatest proportional difference, calculated on the lighter weight, is recorded in the case of lithium, where it amounts to one sixth. It is about one tenth in the case of boron, neon, argon and krypton.

(c) *The Number of Electrons in the Nucleus Tends to be Even.*—This rule expresses the fact that in the majority of cases even

atomic number is associated with even atomic weight and odd with odd. If we consider the three groups of elements, the halogens, the inert gases and the alkali metals, this tendency is very strongly marked. Of the halogens—odd atomic numbers—all 6 (+1?) atomic weights are odd. Of the inert gases—even atomic numbers 13 (+2?) are even and 3 odd. Of the alkali metals—odd atomic numbers—7 are odd and 1 even. In the few known cases of elements of other groups the preponderance, though not so large, is still very marked and nitrogen is the only element yet discovered to consist entirely of atoms the nuclei of which contain an odd number of electrons.

In consequence of the whole number rule there is now no logical difficulty in regarding protons and electrons as the bricks out of which atoms have been constructed. An atom of atomic weight m is turned into one of atomic weight $m+1$ by the addition of a proton plus an electron. If both enter the nucleus, the new element will be an isotope of the old one, for the nuclear charge has not been altered. On the other hand, if the proton alone enters the nucleus and the electron remains outside, an element of next higher atomic number will be formed. If both these new configurations are possible, they will represent elements of the same atomic weight, but with different chemical properties. Such elements are called "isobares" and are actually known.

The case of the element hydrogen is unique; its atom appears to consist of a single proton as nucleus with one planetary electron. It is the only atom in which the nucleus is not composed of a number of protons packed exceedingly closely together. Theory indicates that when such close packing takes place the effective mass will be reduced, so that when four protons are packed together with two electrons to form the helium nucleus, this will have a weight rather less than four times that of the hydrogen nucleus, which is actually the case. It has long been known that the chemical atomic weight of hydrogen was greater than one quarter of that of helium, but so long as fractional weights were general there was no particular need to explain this fact, nor could any definite conclusions be drawn from it. The results obtained by means of the mass-spectrograph remove all doubt on this point, and no matter whether the explanation is to be ascribed to packing or not, we may consider it absolutely certain that if hydrogen is transformed into helium a certain quantity of mass must be annihilated in the process.

The theory of relativity indicates that mass and energy are interchangeable and that in C.G.S. units a mass m at rest may be expressed as a quantity of energy mc^2, where c is the velocity of light. Even in the case of the smallest mass this energy is enor-

mous. If instead of considering single atoms we deal with quantities of matter in ordinary experience the figures for the energy become prodigious. Take the case of 1 gram-atom of hydrogen, that is to say, the quantity of hydrogen in 9 cc of water. If this is entirely transformed into helium the energy liberated will be $0.0077 \times 9 \times 10^{20} = 6.93 \times 10^{18}$ ergs. Expressed in terms of heat this is $1.66 + 10^{11}$ calories or in terms of work, 200,000 kilowatt hours. The transmutation of the hydrogen from 1 pint of water would liberate sufficient energy to drive the *Mauretania* across the Atlantic and back at full speed.

Should the research worker of the future discover some means of releasing this energy in a form which could be employed, the human race will have at its command powers beyond the dreams of scientific fiction; but the remote possibility must always be considered that the energy once liberated will be completely uncontrollable and by its intense violence detonate all neighboring substances. In this event the whole of the hydrogen on the earth might be transformed at once and the success of the experiment published at large to the universe as a new star.

THE MATHEMATICIAN PASCAL, AS PHILOSOPHER AND SAINT
1623-1662[1]

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I

It would be rather extravagant, I suppose, to speak of the many-sided Pascal. That saintly intellectual was not what such a description would be most likely to convey. Certainly Pascal was not a versatile man of the world. In several different fields of human interest, however, in mathematics and physics, in philosophy and religion, historians must take some account of him and biographers may not find his life an altogether simple one.

Of Pascal the mathematician I shall speak only generally and incidentally, and I shall call attention to certain characters or values in the mathematics and mathematicalism of his time; but his actual mathematics, even his very youthful precocity therein and his interesting cycloidal pursuit of Leibnitz and Newton, very properly I must leave to those who are more competent than I to discourse on such indoor sports. Of the scientist, too, widely applauded in his time, and since, for certain productive experiments in physics, I shall also not venture anything technically specific. In my present account of Pascal, philosopher and saint, I would say simply that his physical science and the peculiar freedom and purity of mind natural to mathematics and quite in contrast with the law or dogmatic theology or any institutional formalism, secular or ecclesiastical, must have been important influences not less on his spiritual than on his mental life. They must have been positive factors in the mental complex determining the real purport of his eventual emotional reactions to the thought and life, the philosophy and religious establishments of his time.

Those emotional reactions, as can hardly need saying, were the most expressive and characteristic phases of his life and of them chiefly, of Pascal's rather unconventional place in the history of

[1] This is one of four essays concerned more or less directly with the spiritual values or humanistic implications of the natural sciences and the scientific point of view. The three earlier papers have all been published in THE SCIENTIFIC MONTHLY, as follows: "Philosophy in the service of science," May, 1920; "The philosophy of Herbert Spencer," August, 1920, and "The time of day," November and December, 1923.

philosophy and of his spiritual character and saintliness, I am to speak. These I have found not easily appraised without regard to the scientist's candor towards nature and to the free rationalism, the broad mathematicalism, which were his and which were signs of his time. Mathematician, physicist, God-absorbed devotee, such was Pascal, all three; and, as I would show, not with any real inconsistency.

Both the science and the mathematics, as has to be said, he came finally to abandon, at least outwardly, and he actually passed by any constructively philosophical speculations which those disciplines had prompted in others and certainly might have prompted in him. Perhaps too suddenly he passed from the scientific and intellectual to the religious. Possibly a distinctly and technically philosophical period, tempering the transition, had been more normal and had made the later attitude or condition appear not so flatly opposed or negative to the earlier. Still even flat negation is often very different from what it seems. Seeming reactionary, it may be progressive. To say the least, although flat and sudden, it may be or become only a progressive movement of deepened insight and appreciation. Many a "no" has proved only a profounder "yes." Outward irrationalism, reason apparently quite supplanted by intuition or faith, has sometimes meant only superrationalism; rationalism, not destroyed, but accomplished.

II

To turn directly to the task of this essay, in what qualified sense, if in any sense at all, can Pascal be said to have been a philosopher? Technically, as has been remarked in so many words, he was not a philosopher. He was probably never really interested in working out a system of philosophy. He had the philosophical virtues—patience, sympathy, courage, endurance—but these hardly make him a philosopher professionally. Many of the historians fail to give him more than casual mention, while such as have space and time for him are quite likely to dwell on his antagonism to philosophy rather than on any possible contribution of a positive and constructive nature. Had he only carried out his avowed purpose of something in the manner of a systematic theology, in which he was to answer conclusively and comprehensively the opponents of the neo-Augustinian Jansenists, with whom he had associated himself, there might have been a good case for a more direct inclusion in the histories of philosophy than usually accorded him. In his time conspicuously all philosophy was still very consciously theological, theistically so or atheistically. But temperament as well as health, if the two be separable, made him disinclined to

any material constructions of reason. He could be a scientist for a time or a mathematician, but never really philosopher or theologian. The dominant systematic thought of his day, quite as theological as philosophical, he openly disparaged. So, contemporary with Descartes and Descartes' followers, Geulincx and Malebranche and Spinoza, all sharing with him the interest in mathematics and physical science and all positively theistic when not quite pantheistic, he was, spite of that common interest, anti-Cartesian.

More than this, his general mood was, or certainly came to be, very skeptical. Doubt had actually made Descartes and his philosophy, but Pascal came to declare that all the philosophy, evidently meaning all the systematic thinking, all the rational construction in the world was not worth an hour's attention. He was, then, a profounder skeptic than Descartes. Avoiding applicable systematic thought altogether, he had also left the pure, free knowledge of mathematics, which of course got its exactness and rational truth at expense of applicability and which for being so formal only gave a sort of visionary gnosticism, and turned to the more practical self-evidences, the immediate insights, of religion. So, as a skeptic, did he even outrun doubt itself.

Small wonder that he has not seemed quite respectable or technically correct among philosophers. Philosophical doubt must mind the traffic ordinances. It must not go too fast for safe and systematic reasoning. Yet speed, or doubt even to the point of irrationalism, is sometimes justified and Pascal, in my opinion, deserves a place even in the histories of systematic philosophy. He made, not the usual, but nevertheless a real contribution. I would not injure serious discussion by a humor that may seem strained. Pascal, however, doubts all philosophy very much as Epimenides, as the only honest Cretan, doubted the honesty of *all* Cretans. Pascal philosophized a good deal, but to the cherished refrain that all philosophy was quite in vain, meaning possibly, not that there was no truth anywhere, but that philosophy, like many another thing in life, to gain its soul must lose its world.

"There is nothing," he says, "so in conformity with reason as the disavowal of the supremacy of reason." And again: "Two extremes: to exclude reason; to admit reason only." So in faith he found, when all is said, not unreason, but even more reason than in reason itself. Even philosophically there was something constructive in that. As philosophy is only superrational science, so religion, after Pascal, may be only superrational philosophy.

If what has now been said be correct or even plausible, the expression of Pascal's skepticism in his life may have a different meaning from what appears to casual view. In particular the anti-Cartesianism to which he came and with which came his retire-

ment to the Abbey of Port Royal, would appear to be, say what one may of the great change in his life which almost over night seemed to transform the scientist and mathematician and perhaps potential Cartesian into a religious recluse and saint, no mere "translation" or "conversion" in any orthodox sense. By no means was it an awakening merely to some seventeenth century Fundamentalism. Nor will Pascal's great love for his sister, already conspicuously identified with the Port Royal group, or the accident or shock of 1649 afford adequate explanation. Moreover, there can be no satisfaction in treating Pascal as just one more psychopathic case. In Pascal after 1649, whatever the attending incidents or conditions, I see, I think with sufficient clearness, the open, released expression of implied but theretofore largely suppressed attitudes or feelings, not merely of the Cartesian philosophy with its coincident proofs of God and of a mechanical natural or physical world, but also of that more general rationalism, the wide mathematicalism of the time, then so significant at least not less religiously than naturalistically. I mean, again, that the mental complex and general import of that rationalism gave special character to Pascal's awakened religious insight and feeling. Even as if out-Descartes-ing or outspeeding Descartes, Pascal simply at that crisis became what any good and well-behaved Cartesian, if realizing the emotional and spiritual values, while escaping the mere rational forms, of Cartesianism or of the general idealistic rationalism, might have become. Shock of some sort and the deep experience of it may have been important as proximate cause; outwardly, too, the ensuing change may resemble an orthodox transfiguration; but not so easily may either the leopard change his spots or the intellectual his complexes.

III

A little generalization, if not too stimulating, is sometimes good for the mind.

One may well wonder if intellectuals of any stripe or spot do not commonly fail to realize, at least so long as they remain intellectually garbed and motivated, that their concepts and attitudes, their mental abstractions, methods and constructions, involving as they do both specific form and specific content, must always be potent at least with latent emotional possibilities, which sometimes have to find release and which upon release, even while taking anti-intellectualistic forms, are or properly may be only natural and evolutional expressions of the very mental life that they appear to supplant. Thought, in other words, always has values as well as forms and these values have to be realized, the intellectual giving

place to the emotional, intuitive and practical. The natural end of thought is will and where will is there value is. Again, perhaps with unnecessary repetition, there can be no reasoning without a life, even a superrational life behind it and sooner or later this superrational life must quicken the life of reason and so lead reason itself to find its own realization in feeling, heart, immediate insight and in the action so induced.

Historically or biographically, as I would submit, eras or periods of emotional insight or intuition are significant, of course for their often very obtrusive defiance of reason, but also and more positively for the way in which they show reason with its ways and forms from being held and cultivated for its own sake become only mediate and made quite subordinate to the life that is rationally not normal. "All our reason," wrote Pascal, "reduces itself to feeling. . . . . . We should have a rule. Reason offers itself; but it is pliable in every sense; and thus there is no rule."

Quite to the point, too, is another general fact. At least we may count it as another, although it is really only an expansion of what has just been remarked. Utilitarianism lives at least next door to rationalism. Throughout all the departments of life reason has ever made the sacred, conservatively cherished things, customs, institutions, standards, only so many utilities, so many means or symbols of some broadened or generalized end instead of any longer ends in themselves. Reason, in short, not merely rationalizes but also secularizes what it touches, making—if with whatever compounded offense I may borrow a startling if not profane pun—even divine Zeus only the Zeusful or—now to make prompt payment in kind for the loan—the magnificent Louis only a common and exchangeable *louis d'or*. Yet reason itself, while inducing such changes, never really completes the secularization. It may release to cold and calculating exploitation once cherished institutes of church or state, of morality or industry, but for full release and free use it lacks a needed abandon and the courage and adventure of abandon. Its utilitarianism is still in effect conservative or miserly, always making reservations, being still narrow in its spirit, however broadly rationalistic. For full release and free use, life taking quite to itself what has been fabricated for it, reason itself must turn only means to an end and give first place to feeling or faith. The very skeptical attitude that effects such a change—shown, for example, in the time of the Sophists and the Socratic philosophers as well as in the seventeenth and eighteenth centuries—has always been a solvent by which life has come to use freely, even with abandon that may suggest violence, instead of just hoarding intact, its various achieved and for a time cherished devices. Moreover, when at last the free, full use comes, reason having quite

yielded to emotional insight, and when accordingly the secular and useful things have lost their artificiality, being once more even as means or symbols intimately identified with life itself, these very things may recover the direct and vital reality or value which for a time the formal reason had seemed to deny them.

An example of the feeling or faith, of the irrationalism and abandon, of the virtual superrationalism, of which I have been speaking, can be seen in the century following that of Pascal and at least in a general way may assist understanding of our philosopher-saint. In the later century the rationalization and secularization of Christendom's customs and institutions had become very general and very evident. I have in mind a general situation, but I am thinking specially of Diderot and the Encyclopedists and I am recalling how Rousseau, as if the irrationalist in the drama, greatly disappointed those intellectuals. Devotees they were of the most rationalistic Illumination and they dreamed—as such Illuminati never should have dreamed!—of bringing everything out into the open and luminous air of reason, of clearing away all mystery and even of listing alphabetically and fully reporting and defining all things on earth and in heaven. So they dreamed and they had been looking hopefully to the young Rousseau as one who was going to add the reasoning powers of his genius to the support and furtherance of their cause. Exactly so at one time might the Cartesians have placed hopes in Pascal. But the young Rousseau, I was recalling, disappointed those visionary Encyclopedists, almost in their very midst raising his passionate and revolutionary outcry against calm, cold reason, its clearness and all its artifices and conceits, and calling earnestly for feeling and heart, for nature and reality, for real life, real justice, real religion, even for a real Christ. It is in truth a far cry from Rousseau to Pascal; but Rousseau was one of the irrationalists or superrationalists of history. In his case, too, abnormal personal experience seems to have acted as a proximate cause of the break with what was vogue among the intellectuals of the time. He cried for reality, asserting his own good will, when by all the standards of civilization his conduct of life had been a notorious failure, and with all this he was sensitive superlatively. David Hume said of him that he had the sensitiveness of one with the outer skin removed and every nerve exposed.

Still the emotional over-sensitive Rousseau did not deny reason or the worth of its manifestations in law and order. He simply insisted on its or their only mediate character and accordingly quite subordinated reason to nature and reality. By and of themselves the constructions of reason, law and order, boasted signs of civilization, were for him in some sense unreal, breeding only inequalities among men, injustice and artificiality generally; but, given their

proper place, made secondary and merely instrumental, they had a place in real life and partook of it, carrying it forward, and contributing to its worth instead of betraying it. Reason and its law for real life, not life for reason and its law, has been a principle of progress and strikes me as very near to the meaning of Rousseau's call for heart and reality.

Philosopher of the French Revolution and its abandon! So often has Rousseau been represented. That revolution, however, is best looked upon as but an unusually violent episode in the social and political evolution of the time through which conditions of special privilege and inequality were opened as opportunities to all. Institutes of special interests became public media or instruments. By subordination of the old order as rationalized and secularized, to "Liberty! Fraternity! Equality!" not only was the magnificent Bourbon made merely so much exchangeable coin, but also the traditionally august things generally were put within popular reach and, from seeming dead, were made to live again. *Le roi est mort! Vive le roi!* Reason had secularized what feeling, not without some gestures of violence, sanctified anew by putting to progressive use.

IV

But let us have done with digressive generalization, however good it be for the mind, and with the emotional and irrational Rousseau, who certainly did not frequent the streets or walks of life best known to Pascal. Of course I mean nothing uncanny; but, while I have been speaking of Rousseau, Pascal himself must have been waiting aside, waiting and greatly wondering. That in any way his anti-Cartesianism or his irrationalism should be supposed commensurate with the passion of Rousseau! Rousseau was a social and political revolutionist or evolutionist; Pascal, only some sort of a philosopher and, in particular, a religious recluse and saint, who was also, yet very gently and in no sectarian sense, say in character and spirit rather than in avowal or overt act, a real protestant.

Pascal may not have had any very direct influence on life in general, on so-called practical life, social or political, whether for his own time or later; but he did effect something for religion and religious experience and in what he did here his work has a certain analogy with that of Rousseau. Thus he greatly broadened and deepened the mediative value of the institutes, the rites and sacraments of the church, with which, especially after 1653, he became so intimately identified. Perhaps, had he not been an invalid, had he possessed more vigor, he had not adhered so closely to the church as it then was; he might have not merely enhanced and enriched

the mediation, but also demanded and devised changes in the medium: but so to speculate is rather futile and in any case our interest here must be primarily in what he did, not in what he might have done. His actual achievement, too, was great and it had a quality worth while in itself and possibly quite lacking had he been able to be more practically inventive and openly progressive. Enough for us that his free broad spirit has belonged, not just to the visible institution of his time, but to the invisible, to religion then and since.

To begin with, spite of his anti-Cartesianism, Pascal really did carry on for Cartesianism and for the general mathematicalism and rationalism of the time; feeling these, however, rather than thinking them, making them enrich life emotionally rather than satisfy it only intellectually; realizing, even under the routine of a medieval abbey, their greater spiritual value. Like many other saintly, if not always sainted, individuals of the Roman Church he made the traditional tenets and the sacraments spiritual symbols and cults, using them as so many media in expression of an expansive Theism and broadly sympathetic humanism and so proving himself in reality more modern than medieval, for his time more naturalistic and humanistic and individualistic than institutional. It is true that in all its rites and disciplines his religious life, besides being outwardly conservative and reactionary, was very realistic, sensuously so; but I submit that for him, as to some extent for the medieval church generally, there was modern value in that sensuous realism. Also, if so I may express myself, the window of Pascal's cell was never really closed to the world that such men as Galileo and Descartes had discovered and as was already, for all whose windows and hearts were open, enriching wonderfully the old theism.

In the mathematicalism of the time, as developed by Descartes or by others, there really moved and moved forcefully the very attitudes and emotions that came to possess Pascal so completely. For evidence we should remember that to all intents and purposes the mathematical rationalism with its splendid enlargement and liberation of thought not so much replaced as continued the medieval formal and deductive logic, pious science of the Word, the λόγος. The former, in fact, may be regarded as only a brilliant generalization from the latter, as if deductive thinking had simply broken away from its tether of institution or dogma or single "given" or datum and entered the wider region of all data, say of all possible hypotheses. Even must one wonder if we ever would have had the mathematics without the earlier logic and its discipline. Many a churchman certainly was schooled in the logic only to be graduated a brilliant as disciplined mathematician. On this

bit of speculation, however, I need not dwell. Here it quite suffices, I think, to say that many have missed the great spirit of the medieval scholasticism, the reverence of its logic and the spiritual realism of its intellectual formalism and artificiality; and, missing these, they have not been disposed to appreciate how the ensuing seventeenth century mathematics, only fulfilling the logic by realizing and freeing the spirit of it and escaping the narrow letter, was also in the value given then, in the feeling of many of the mathematicians themselves and in the actual uses to which the great method of mathematics came to be put, a sacred science, being spiritually, not merely physically significant.

Most of us, quite unfortunately for full understanding, have commonly associated that mathematics and even the broader mathematicalism only with the rise of physics and mechanics or of a materio-mechanicalistic philosophy. Possibly as historians we have been able to drive only one horse, whereas whole and accurate history, I venture to insist, is not by any means so easy or simple, being actually drawn by two, not just by one with perhaps a colt. At least, as to the matter in hand many of us have not realized, even if we have known, that politics and morals and above all theology, from being at once narrowly institutional or legalistic and creationalistic, were also become with most important results mathematicalistic and mechanicalistic, the latter even to the point of suggesting a sort of automatism in place of the earlier creationism or control *ab extra*. All that those various terms mean, as I have just used them, may not at first appear; but it is at least clearly important to their meaning that the natural sciences and the humanities, including even theology, were met in the common method of mathematics. It may also be added in passing that quite consistently with that common method, the humanities, concerned no longer with traditional authority and institutional conformity but primarily with general and essential principles, with native powers and potentialities, capable of unlimited expressions or applications, were become or becoming directly human and individualistic, while the sciences on their side were inductive, objective, naturalistic. So, truly, had seventeenth century mathematics the historic value of the λόγος, mediating as it did in a timely way between the spiritual and the natural or physical.

Giordano Bruno (1548–1600), something of a mathematician, as well as psychologist and astronomer, and a good deal of a pantheist, was a martyred pioneer of those who can give testimony to mathematics at that time being significant at least not less for religion and the other humanities than for physical science. The moral and political writings of Thomas Hobbes (1588–1679), so formally rationalistic and *a priori,* afford from English history an

excellent illustration of mathematics as a humanity. Benedict Spinoza (1632–1677) gave not merely the spirit but the actual form and manner of a treatise of geometry to his famous *Ethics* and in this geometrical treatise, in its several Euclidean books, God and Nature, Mind and Body, Emotions, Bondage and Freedom, he included theology, philosophy of nature, theory of knowledge and morals and religion. Alexander Pope (1688–1745) and others like him across the channel well reflected the spirit of the time in their crystal clear and automobilic verse. A statement of Hume belongs, it is true, to the later time of Rousseau, but it expresses the tendency distinctly evident and, as we have seen, often exemplified in Pascal's century. Hume, who was fêted in Paris, saw no reason why even politics should not become a science as exact as mathematics. Doubtless to-day there are persons who wish Hume's dream might be realized! But plainly in the century of Pascal and the Cartesians mathematics, whatever else must be said of it, was a humanity comprehensively and profoundly.

For the whole Cartesian School this was eminently true. For them the very values of religion were in mathematics, making it, as was said above, a sacred science. With Descartes himself it brought not merely a remarkable expansion of geometry, effected by the admission of algebra and the device of coordinates to geometry, but also a proof of the existence of God which, judged by its sequel in Malebranche and Spinoza, freed theology as much as it had freed geometry, expanding as it did the life and purposes of the deity from the régime of the traditional church to the whole mechanism of nature. In Book I of his *Ethics,* Spinoza proved mathematically, if not the identity, at least the virtual unity of God and nature. For Geulincx and Malebranche, both mathematicians and pantheists, life—or motion—and vision—or thought—were "in God," in the veracious God, veracious as mathematics.

So it is indeed well to remember that the humanities as well as the sciences were dependent on mathematics, that contemporary with Galileo (1564–1642) and others studying the physical universe, there were the devout Cartesians. I speak only as a historian, but Pascal, reading the Psalms, out of the rationalism of his time could give special meaning to the nineteenth: "The Heavens declare the glory of God and the firmament sheweth his handiwork."

To the sacred science of his time, then, to the religious use and value of it, Pascal responded. Not a Cartesian technically or formally, not a philosopher of any ism, disposed on the contrary to disparage formal philosophy, he still can be regarded as deserving place in the history of philosophy for really being an important exponent or interpreter of the thought of his time, realizing emotions and values latent in it and so belonging to its meaning.

Was he, therefore, as has been suggested, super-philosophical rather than really anti-philosophical? Let a recurrent idea, or refrain, of his own writings give at least a partial answer. Nothing, as he keeps saying in various ways, is so consistently and consequentially rational as that reason is not all or philosophical as that no philosophy is final. To quote directly and at random from his "Thoughts":

> We know the truth not only by reasoning but by feeling and by a vivid and luminous power of direct comprehension and only by this last faculty do we really discern first principles. . . .
>
> If we submit everything to reason our religion will have no mysterious and supernatural element. If we offend the principle of reason our religion will be absurd and ridiculous. . . .
>
> Man is but a reed, but he is a thinking reed.

V

Yet many, I doubt not, will continue to think of Pascal as a traitor to the intellectual, to science and philosophy and reason, and will regard him, however admirable in his character of a saint, as only a reactionary who spurned instead of in any way fulfilling or valuing positively the science and philosophy of his time. Moreover, as must be admitted, they can make a plausible case. But they will be regarding the more external evidence and neglecting the real spirit of the man himself. Here is their case. He became a recluse in an abbey established in the thirteenth century and still on the whole in good thirteenth century character. With other followers of Jansen he went back to St. Augustine of the still earlier fourth century. He was mystical, ascetic, supernaturalistic. He even wrote very often in the language, to use our current term, of a Fundamentalist. But, so much said and emphasized, their case has its weakness. Of course, even such appearances may be deceptive. Returns to the past are ever of two sorts and to casual observation one sort may not look different from the other. Moreover, the neo-Augustinianism was actually broadening and liberating to thirteenth century establishments. Jansenism, again, was a movement against Jesuitism. So, if Pascal went back to the past, he was hardly a mere reactionary. He went back, not for dogmas, but for values; not for finalities, but for sanctified symbols. At the Abbey, as I have suggested, his windows were open to the new world of the time and his disciplines, however reminiscent of earlier centuries, were in worship of the expanded God of Bruno, the Cartesians—some of whom were also Jansenists—and Spinoza. There always may be, as in Pascal's case, as in Rousseau's case, something progressive, something even revolutionary in a cry, spoken or implied, for a return to the past. One may recall the past simply to hoard it or as with Pascal really to use it in the present.

Pascal's physical weakness after 1649 doubtless did affect the manner and meaning of his retirement and his outward defection from the intellectual for the religious life, but, under whatever qualifications this might entail, there is abundant evidence, which is not without its moral for certain reactionaries of to-day, that his retirement and reaction were without either bigotry or fear of truth. For the alarmed and bigoted reactionary "the end justifies the means" with a meaning which no one could ever suppose to be included in Pascal's philosophy of life. By his spiritual, not dogmatic fundamentalism, Pascal may properly be grouped with certain saints who returned to origins and fundamentals in a way that was indeed painful and was often too literally realistic, but who by making their religion so intimately personal instead of institutional were real Catholic forerunners of Protestantism. Did they not assert their individual independence and, like Pascal, have their windows open to nature?

Pascal, too, never really ceased to be a thinker, psychological, humanistic, candidly naturalistic. His "Thoughts," true to this title, show a reflective mind. More sporadic and aphoristic than systematic, it is true, they nevertheless are reflective and demonstrative, not dogmatic, in their spirit. Nowhere, so far as I have found, is there any defiance of science or reason. Were the "Thoughts" to be initialed, the appropriate letters in signature would be Q. E. D., not W. J. B. Living to-day, Pascal would not have denied evolution.

Primarily Pascal stood for spiritual values, not for outgrown and rationally no longer tenable doctrines. "If we offend the principle of reason our religion will be absurd and ridiculous." Pascal, I repeat, greatly broadened and deepened the mediative value of the rites and sacraments of the church. Stronger, he might have done more; but he did so much.

VI

May I conclude with some possible applications to the present day?

So far I may have seemed to be speaking in an untimely way, arousing surprise. I have been, or have seemed, so ready to accept the language and take the standpoint, not merely of general orthodox theism, but also even of Pascal's Romanism. Yet, attempting to write as historian and biographer, how could I have done differently? Seeking to represent the Augustinian Pascal and his time, quite apart from any religious color of my own or any lack of such color, I could not be true historian without the sympathy I have shown. Lacking such sympathy, I had in so many words accused Pascal of not being genuine. He certainly was genuine and true to his time.

In my sympathy with Pascal and applause of him I may, furthermore, have caused alarm among the intellectuals, philosophical, mathematical or scientific, who now attend. "Would he start a revival among us?" I hear someone ask: "Would he summon us to the front pews, to which the scientist and mathematician, Pascal, finally came and ask us also to become devout theists or retiring saints instead of critical and systematic intellectuals? Would he have us believe that naturally in our intellectual life there lurks any such danger?" Let no one be so frightened. Here and now is no intent of a revival. Also it may even be that twentieth century Illuminati are latently also Religiosi and that our various intellectual isms and systems hold spiritual values which some day will be realized by others if not by ourselves; but my present interest has been simply to understand Pascal—the Pascal between the lines of the formal life of his time—and to make clear for any time, our own or any other, as well as his, the general principle under which he can be understood. Given isms or systems, they can not always remain merely intellectual or rationalistic; in them lie more than so many facts and formulae; in them are present and potent specific emotional and volitional values.

Many there are to-day for whom the world seems to be only a world of facts and formulae. Hiding their inevitable interest in it or their own conceit of wisdom about it, either of these certainly implying real valuation, they would represent it only as a world of facts and formulae. Perhaps they treat the values as only more facts, humanistic instead of naturalistic facts. Perhaps they are satisfied that at best the values, so far as not just facts, are only relative, subjective, virtually elusive and unreal, varying with the weather. But as to their boasted facts and formulae, are these on their side so real and stable, so true and reliable that the world of values may be disparaged and discredited for its fluency and adaptability? I would be the last to insist on two worlds or on any real dualism of facts and values. Values, however, are as real as facts, so that quite contrary to what many have been contending in these days of naturalism and science, no factual realism can be adequate to, or exhaustive of, reality or be in its so-called realism more than an important half-truth. A realism proceeding from the facts and formulae of natural science can at best be only an abstract and artificial construction. Can values be objectively rationalized or facts be confused with feeling and will?

I am no theologian and theologically I certainly have no brief for Pascal. From anything of that sort I am farther removed than what I have been saying here may have seemed to imply; but to the extent in which Pascal caught and expressed, as if in a counter

abstraction and construction, the feeling and spiritual meaning of the rationalism and broad mechanicalism of his time, expanding the old theism, purifying and deepening the accompanying personal individualism and making even traditional rites and disciplines serve his naturalistic pantheism and his virtual protestantism, I have found myself constrained to approve and applaud.

A final suggestion seems not impertinent even in this place. Our current newspapers and journals are each week more and more given to references to a coming spiritual awakening. Some would explain such things as give ground for these references by calling them gestures of weakness. So always in their view has idealism or spiritual realism been a sign only of atrophy or "nerves" or defect and natural incompetence of some kind. The substantial progress of thought, except for somehow persistent and discouraging idealistic lapses, has been a gradually preparing triumph of so-called natural realism! But such explanation can not satisfy either history or the present day. One-horse thinking I have called it. Let it stand and the sort of thing that Fundamentalism is exhibiting seems inevitable. Insist only on the natural facts and formulae and you invite a purely reactionary Fundamentalism, its ignorance and narrowness, its timid retirement and bigotry. With candid acceptance of the facts, then, there must be also as the only way in which really to complete the realism or the naturalism, emotional and volitional valuation of them. In other words, such movements as Fundamentalism must be met in kind, and met in kind, not indirectly and half-heartedly, not with uncertain and equivocal adjectives, but directly and positively, with substantial and unequivocal nouns.

Does this mean that the idealists should propose a new vocabulary for their wares, bringing their nouns up to date? Doubtless something might be said in support of an affirmative answer to that question. The call for a new language when meanings have greatly changed is a familiar one; as familiar, too, as unwise and unfair. But, whatever the grounds for it, surely idealism, or the realism of values, ought not to be required to devise new terms until the counter abstraction, the realism of facts and formulae, is ready on its side, instead of any longer talking of nature and matter, of force and life, to tell us of kibosh and woppy, of joteb and jazz, or of other things as novel and startlingly up-to-date, as also uninteresting.

THE VALUE OF INCONSISTENCY

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"A FOOLISH consistency is the hobgoblin of little minds," was the opinion of Emerson in an essay on "Self-reliance." He thought that one should speak in hard words what he thinks to-day and to-morrow what to-morrow he thinks, though the two might be completely contradictory. This opinion is a frank acknowledgment of growth in comprehension or of significant changes in circumstances or of both. But it is not universally accepted. In fact, quite commonly consistency in belief is thought to be a matter of unexceptional necessity for the individual. It is an accompaniment of sincerity, thoroughness and honesty. An inconsistent candidate for office will not get our votes, for in inconsistency there is a flavor of untrustworthiness, indeed of dishonesty. So firmly fixed is the faith in consistency that in the life of the individual it has been accepted as a virtue possessing an inherent value independent of circumstances.

Doubtless the origin of this faith in an individual can be found in his past experiences. A child as a listener to debates in the family circle learns the crushing influence of the proven charge of inconsistency. The pulpit expounds doctrines that give satisfaction not only in themselves but more importantly as component parts of a consistent system of belief. Even arithmetic teaches the necessity of consistency in the use of units such as feet and yards, if the correct answer is to be obtained. When the child becomes a college student there is no abatement of instruction in the virtue of consistency. Thus one comes to regard that virtue as really inherently valuable and always essential to sound and permanent progress. Such instruction in the use of consistent reasoning is commendable. An opposite teaching would be disastrous. But the question is raised: Is consistency inherently valuable and always essential? That the ultimate is wholly consistent is not here doubted. Moreover, one may take the view that, in view of this admission, consistency must be regarded as inherently valuable and always trustworthy. But this discussion refers not at all to the ultimate, but to the thoughts and reasoning of the individual. With this understanding, one can at once recognize the possibility of the measure of the value of consistency by results achieved through its application.

It is easily seen that an expectation of the possibility of the constant condition of consistency is not justified. For consider the

nature of truth. We do not have it all, but only fragments of truth, and since each of these can not be perfect in every respect, they may overlap in their applicability and in this overlapping region may not be in agreement. An example in physical science will illustrate. Consider the physicist's knowledge of interatomic forces. There is undoubtedly an attraction between bodies of matter, and to this is given the name gravitation. The law of gravitation, whether one accepts the simple form of Newton or the amended one of Einstein, asserts that the attraction increases with a decrease of distance between the bodies. But this law, which is believed, is inconsistent with certain phenomena found at small distances. In crystals the atoms are in orderly array with their centers at fixed mean distances which are not limited by contact but evidently by forces which prevent a nearer approach. Obviously, the law of gravitation is not in harmony with this fact, for it claims that attraction is always present. The supposition that there may at these small distances exist a new type of force in addition to that of gravitation is merely an effort to remove the disagreement between accepted "law" and experiment. The physicist admits the contradiction, asserts that you have applied the law at distances not justifiable by experiment and that the complete law applicable to all distances has yet to be ascertained. The law of gravitation is a fragment of truth, not perfect, and consequently not always in agreement with the actual phenomena. The physicist at every boundary of his knowledge sees the chance of contradiction of theories or scientific beliefs. It is moreover strikingly significant that in these inconsistencies he finds the challenge that leads to new investigations and to new knowledge.

From the foregoing it may be observed that the considerations of this paper are not limited to the inconsistencies to which Emerson refers. These arise from opinions held at different times. It is here purposed to show that *simultaneous* inconsistency or holding at the same moment contradictory opinions or theories is not wholly undesirable and may even be a necessity for progress. Science and more particularly physical science has, by the application of what is known as the scientific method, produced a permanent body of knowledge which is proving exceedingly useful to mankind. Physical science is always logical, but it often limits its effort to the clearing up of a small region of knowledge, and in so doing establishes consistent views, not necessarily in science as a whole, but in this limited region. In short, progress through consistency in a small domain is sometimes a desideratum even at the expense of consistency throughout the entire body of knowledge. Thus it happens that a simultaneous inconsistency can be helpful to progress in physical science, and, if so, surely in less mathematical and less

logical fields this type of inconsistency may prove to be of even greater value. This presentation substitutes concrete evidence for an argument covering the entire range of man's thought, expecting that a definite knowledge of the possible value of inconsistency in physics, for example, will thereby carry a reasonable assurance of the existence of this value in all fields of knowledge.

That the ultimate goal, truth, is everywhere consistent should not cause a reliance in such a harmony in any of the series of immediate goals that are attained in man's progress. In fact, too strong a hope for consistency may become an actual hindrance. This was Oersted's experience when endeavoring to discover the effect of electricity from galvanic cells upon a magnetic needle. The phenomenon itself is experimentally simple. When a current in a wire is held over a magnetic needle, the latter turns and would finally point at right angles to the wire were the current the only directive force. In Oersted's time the experiment was not difficult of performance so far as equipment was concerned, for the galvanic cell and magnetic needle were well known. The real difficulty which Oersted had the honor to overcome was that of experimenting in a manner inconsistent with the thought of the day. Oersted states in his original report of these researches that he experimented with a closed galvanic circuit and not with an open one as had been unsuccessfully tried by several distinguished physicists. Any ignorant boy might have tried one method as readily as the other. But learned physicists, fully aware of the best thought of the day, failed to find the phenomenon because they experimented in a manner consistent with current views. Yet how importantly did consistency retard progress, for upon the magnetic effect of a current of electricity rests all the modern utilization of electricity.

Another illustration is found in the life of Faraday, the great discoverer of induced currents. He was delayed to an unbelievable extent by his attempt to be consistent in his reasoning. He knew that, as Oersted had shown, a constant current produced a constant magnetic field. If there was a reciprocal action, then a constant magnetic field would produce a steady current. He attempted patiently to prove this but failed. Not until he laid aside his attempt at consistency did he learn the actual relation, namely, that a changing magnetic field and only a changing one will produce an electric current. If he had been unhampered by apparent consistency in thought, one experiment would have been as easily and as quickly tried as the other. In view of such actual occurrences with the world's greatest investigators, it is easy to believe that thousands of experimental efforts have been brought to nought because the investigators did not overcome the hampering influence of consistency with known facts.

It might be anticipated that if consistency may be a definite hindrance then at times the adoption of an inconsistent theory may prove advantageous to progress. Such is the fact. When Bohr first described his orbital theory of the structure of the atom, many physicists were dismayed because Bohr assumed the truth of the recognized laws of mechanics and of electricity *only in part. Without any other justification than the results achieved thereby* he made an assumption contrary to an important conclusion from these laws. This heresy of eleven years ago is to-day orthodoxy and yet without any other kind of justification found for the assumption than the one Bohr made. The confusion arising from inconsistency has not been removed, but the essence of the orbital theory is accepted to-day as a permanent contribution to physics.

Other illustrations of the adoption of theories inconsistent with those already accepted may be cited. For example, a mathematical expression for the radiation from black bodies could not be obtained by adhering to classical (or accepted) doctrines. Only when Planck broke away from them did a theory in agreement with the facts appear. So common has this apparent breaking with the past been productive that its significance should be emphasized. The great leaders in physics are not unstable radicals. They are in fact very conservative. They do not propose new theories in order to indulge in heresy with its attendant compensations in notoriety, but they propose theories that are needed to explain phenomena which are not understood in the light of the older views. The old is not cast aside. The new compels temporary acceptance on logical grounds. For the most part the contradictions between the new and the old exist in a region of experiment into which attempts had been made to extend the old, though not without logical reasoning. Always the old view is retained where it serves best to relate the facts and the new view is applied only where it gives the best explanation. Thus the leaders and indeed all who follow them accept doctrines that are not consistent in overlapping regions. The physicist of to-day may well be called a polydogmatist. His inconsistency does not cause him worry, for he realizes how far distant is the goal and how unproductive would be the requirement of consistency along the journey. Then, too, he becomes more aware that, after all, a doctrine is a thing to be practiced and not believed in the sense of inactive acceptance. His main object is to apply new doctrines, discover new facts thereby and thus to make progress.

Illustrations have just been given of the negative value of attempted consistency and of the positive value of inconsistency. No argument has been made to establish an inherent value for conflicts in views in the mind of an individual. The illustrations are merely

indicative of a fact, and not a theory, that progress in science is frequently made by the investigator when he harbors theories not free from discrepancies and contradictions. And the cause of progress in science is surely representative of most intellectual endeavors of man. Such evidences, if faced frankly, destroy one's confidence in the adoption of consistency as an ideal in every thought process. An effective and desirable combination of consistent reasoning and incompatible beliefs may be described as a striving for consistency in limited regions of thought, each one as large as practicable, accompanied by a regard for the consistency of the whole as a consideration of much less immediate importance.

The phrase "separate compartments" is sometimes used to describe the structure erected in the mind of one who has not a consistent belief. If one can not reconcile his beliefs, he must prevent quarrels among them by effective mental separators that forbid movement or exchange of thought from one realm to another. It is difficult to conceive of a great mind engaging in such an arbitrary means of securing mental peace. But the foregoing shows that in achieving progress such compartments are sometimes essential, for the new theory must have a chance. It must be tested in all directions and the whole measure of its truth taken without interference on the part of the old. The compartments are not consciously erected by the investigator, for he is absorbed in the outcome of his own efforts. He does not have time to become concerned with any possible inherent value in complete freedom from contradiction. Readers of the life of the great Faraday have wondered about his willingness to have such compartments. He would scarcely accept the experimental findings of another physicist without testing them out for himself. Yet he contentedly belonged to a small and very credal religious sect until expelled from it because he dined with the Queen on Sunday. Faraday waited patiently until he was reinstated in the fold. Tyndall, in referring to Faraday's religious view, states, "He believed the human heart to be swayed by a power to which science or logic opened no approach." In a letter to Lady Lovelace, Faraday wrote, "There is no philosophy in my religion. . . . I do not think it at all necessary to tie the study of natural science and religion together, and, in my intercourse with my fellow-creatures, that which is religious and that which is philosophical have ever been two distinct things." In the light of what has been herein set forth, Faraday's position can be understood. He was content with two compartments because he was so busily engaged in one that he did not have either time or interest in the problem of reconciling the two. Doubtless he also saw that consistency is not an inherent virtue and that indifference to it in overlapping fields may be the attitude of the mind that produces the most rapid prog-

ress. Under such circumstances it may be that a great mind erects compartments, but these considerations should not commend compartments as a fixed policy. It is wise, however, to understand clearly that compartments may, in individual cases, prove advantageous to real development. The analogy to the attitude of investigators in science is complete; always an attempt at consistency, but the adoption of inconsistent views if thereby distinct progress can be made. In contrast, one may imagine a mind so absorbed in reconciliation that he fails to contribute to any field of knowledge.

Since the methods of science are logical and not unique, the reader may have confidence that there are cases in all fields of knowledge where a willingness to be inconsistent has a distinct value. And, further, inasmuch as the method of science has proved its worth by the production of results, one may expect a fair inference that the contention in this essay may wisely be extended to one's attitude toward the political, social and religious questions of the day. It is distressing to witness the somewhat insistent belief of young people that religious faith and scientific knowledge must be in agreement. The scientific method has been adopted extensively in the accumulation of the latter. In religion the same method has been but little used. Although in a measure based upon experience, religion has been accepted more by faith than by experiment. It is therefore not surprising that the conclusions of theologians do not altogether agree with the views generally accepted in science. That there is no contradiction found in science to the most fundamental concepts of the theologian is far more important than the disagreements in minor details. While every one should wish for no conflict between science and theology, consistency is not an immediate goal and inconsistency must be anticipated as a normal accompaniment of progress in such widely separated fields. He who spends his time attempting to reconcile the teachings of science and of theology surely can not have a very important function in contributing to the progress of either. Scientific theories are to be *lived* and not merely *believed*. He who is engaged in the encouragement of the application of theory in either field is aiding in the progress of the world. By his devotion to a cause and his willingness to be inconsistent without worry, he can make a definite contribution.

Emerson was right; past opinions should not cause excessive mental inertia. But the above conclusions take us much farther. Inconsistency in opinions held at *one* moment may be necessary for progress and the individual should accept this view and cease to regard complete consistency as always either desirable or valuable.

PROGRESS—BY ACCIDENT OR PLAN?

By Professor EZRA BOWEN

LAFAYETTE COLLEGE

PROGRESS is a fact. But it is a painful fact. Can it be made less painful? Let us see. And to this end let us attempt to arrange the facts and principles of human progress in clear and simple pattern.

Progressing means adapting. Man and his setting coming into smoother working adjustment—this is progress.

Two terms appear in the subject of this definition, "man" and "his setting." There are, then, to human progress, two phases: Man's nature changes to meet the conditions of existence; and he modifies the conditions of existence to suit better his present nature. The first proposition offers a study in life, biology; the second a study in livelihood, economics.

Progress of the first sort, biologic progress, is not accident; it is a necessity, a condition to existence. Concurrent building up and breaking down, the central characteristic of life forms, decrees progress—or extinction. And this process is present, in principle, in all that is organic or of an organic nature: in cells, in tissue, in organs, in individuals, in institutions, in society as a whole—concurrent building up and breaking down everywhere, universal to life. But always one outruns the other. There is no poised state in life; there is decay or growth. Progress is necessary to life; and the continuing existence of the human kind is complete testimony to its biologic progress.

But if biologic progress is no accident, neither is it a conscious product. There is no warrant, the biologist says, for belief in the inheritance of acquired characteristic (progress through passing on the acquired betterment of the individual). Nor does a regard for the biologic progress of mankind appear—if at all—except as the barest trace in the general mating motive.

What, then, are the factors in biologic progress? They are three: heredity and variation form each one side of the arch of progress; the keystone is propagation beyond the means of existence.

Heredity may well be considered the first fact of biologic progress, without which all would be senseless confusion. It is the tendency in individuals to resemble their progenitors. And, were

heredity the single fact of regeneration, each successive generation would be exactly like the preceding—in the same sense that one sheet of two cent stamps is like another struck from the same plate. But superposed, there is the fact of variation.

Variation is the tendency in individuals toward difference, in ways and degrees indefinite, but always within the meaning of the concept of heredity.

When the idea of variation is added to the idea of heredity, we see the vehicle of biologic progress complete; but still there is no motor. Propagation beyond the means of existence—here is our motor. This is the dynamic of biologic progress.[1]

Heredity insuring integrity, variation forming a basis for selection, and close-fisted nature, acting through over-propagation, doing the selecting—this is the progress scheme, complete. Nature takes the individual as he comes from the shaping hands of the sisters, heredity and variation; slams him, kicking, into an almost rigid mold, the conditions of existence. If he soon stops kicking and passes on to his reward, it is because he did not fit in with the conditions of existence. Others fit and are called fit. They propagate, and heredity shapes their children a little more to the mold, more on the average than were they and their non-fitting brothers, taken together—a millionth of a hair's breadth, perhaps. No whit better than its actual progenitors, a generation is, nevertheless, a millionth of a hair's breadth better than the whole of the preceding, misfits and fits lumped. Simply, the misfits perish before the time of propagation, or their children perish soon thereafter—only the more fit are reproduced. This is the natural method of progress; its price is eternal destruction.

The direct cause of this destruction, over-propagation, implies constant struggle and no quarter given. All other species must blindly carry on, but man—or some among men—know this grim

[1] Of course it is not, in reality, as simple as this; and what follows also preserves strict accuracy only in bold outline and relative position. The "forces" of heredity and environment, for example, are inseparable, except in complete abstraction—and so are heredity and variation. In fact, these three, merged to form a new concept of heredity—heredity in a cosmic rather than a parental sense—may be the only hope for the survival of the term heredity in the biologic language. There is a complicated interplay of chromosomes, cytoplasm and external accident that eludes the grasp of any term now in use. A certain egg is compelled by a force within to produce an individual of predetermined characteristics—that concept of heredity is outworn and discarded. It now means but little more than this: A certain frog egg is not predestined to become a frog of definite characteristics and markings, and a second egg to become an equally definite but slightly different frog. Simply, neither will ever become a canary—or even a hop toad. The main force is in negation.

joke. Then why have we not been shown the way to swim out of the terrible waters of over-propagation in which beast, bird, insect, bacteria and man struggle, group against group, individual with individual; wherein two plot and strangle a third that two may live—miserably in the main, but live? Were some prophet to show us that we ought to swim out of the whirlpool of over-propagation—and we did it—should we not, by that act, thwart progress and bring on the ultimate destruction of our kind? For if over-propagation is the motor of progress, and we limit births, are we not destroying the motor, bringing everything to a fatal stop? But what matter—why subject nearly all one generation to grinding, heartbreaking conditions of existence in order that the next may be better (better adapted) by the thickness of a wish? Ridiculous! Limit births and sack progress.

This is the point reached by the birth-controllist; this is his "furtherest north" in the general rush to reach the pole of clear thought in the problems of progress and population.

But it is not necessary to sack progress. For in limiting births you thwart only natural selection; and it is merely some kind of selection that is wanted. Will not conscious selection motor the car of progress more efficiently than the old engine, over-propagation—plus destruction? Beyond a doubt. And that (conscious selection) is the fundamental meaning in eugenics.

Now we can lay out the pattern, complete, of sane biologic progress: Limitations of births to reduce the pressure of the conditions of existence, and then, conscious selection to keep progress in the plan. . . . But this is only half of progress; we have still to consider the economics of it.

Progress is not of two independent kinds, but of two related parts moving in one direction—toward closer adaptation. We have seen that man's nature has been modified favorably, from generation to generation by but infinitesimal degrees. For tens upon tens of thousands of years his ability to modify his setting did not amount to more. But what weal, what wealth, has been piled up in the past one hundred years, in the last quarter century! Wealth, fixed wealth, especially: dwelling places, factories, highways, the housing of commerce, the machinery of transport—these and their like are the huge improvements man has made in the conditions of his existence.

The degree to which man has, in late years, ameliorated the conditions of his existence—an astounding economic progress—seems to many minds to have removed him from the universal strife, the struggle for existence. But these optimists have left

out of account rising standards of living. They have forgotten that human desires increase more rapidly than wealth. And it is, unhappily, the newer, complicated, more urbane desires that receive the greater emphasis. Here is a case from the record of abandoned babies in Minneapolis: A young couple, haled into court, said simply they had decided that either automobile or baby must go. They had given up the baby. Again, nearly 20 per cent. of the school children in the larger cities of the United States are undernourished, and the families of many support a "car"—hardly one foregoes both radio and phonograph. The fol-de-rol and flap-doodle of civilization must at all costs be maintained!

From this it seems quite clear that birth-control, and nothing more, is of no avail. For if the striving, starving family of eight be limited to four, only to afford soiled silks and second-hand motor—little ones still hurrying off to school, in winter, cotton clad and badly nourished—where is the gain? The consumption of goods and services, the utilization of wealth—this, too, must be controlled.

But it is not to be argued for one instant that lower standards of material living must obtain. To the contrary, higher and higher standards are most desirable—and as inevitable as they are good. Simply, the emphasis must be made to fall where it should. And until education has given every individual a sounder set of values, the use of wealth must be directed.

Now we have the pattern of sane progress, all points and lines intact: There must be limitation of births; there must be direction and control in the utilization of wealth—these to give respite, to give slack, to make life for the many an investment rather than a speculation or pure gamble. Then, there must be conscious selection to restore progress to the scheme.

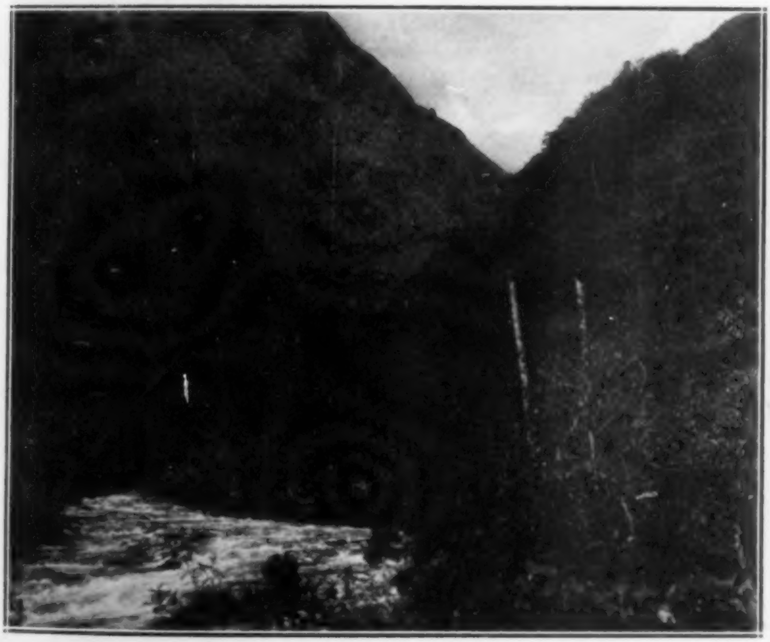
BOTANIZING IN BOLIVIA

By Professor A. S. HITCHCOCK

U. S. DEPARTMENT OF AGRICULTURE

In going from Cuzco to La Paz the traveler passes through Juliaca, taking the branch of the railroad to Puno on Lake Titicaca. Here he transfers to a small but comfortable steamer and during the night crosses the lake to Guaqui, and here takes the train for La Paz. Lake Titicaca is 130 miles long, and as much as 900 feet deep, has an area of about 3,200 square miles and lies between Peru and Bolivia at an altitude of 12,500 feet. The scenery is not striking, as there are no high mountains in the immediate vicinity. The drainage system has no outlet to the sea; the waters of the lake flow south and are finally lost in the great alkali desert of southwestern Bolivia.

The plain to the east of the lake rises gradually to the rim of the valley of La Paz where it is 13,500 feet. It is a remarkable and surprising sight as one approaches the edge of the puna or plain and suddenly looks down on the city of La Paz, 1,500 feet below.



Scene in the Yungas
Semitropical vegetation of a valley.

A VILLAGE ON THE WAY TO THE YUNGAS

The train changes here to electricity and meanders down the steep slopes of the valley to the city.

At La Paz I had a good room in the Hotel Paris facing east and had a magnificent view of the great snow-capped Illimani 30 miles distant, rising to the height of 6,619 meters (21,700 feet). This imposing peak dominates the view here much as Ranier and Shasta

A DRY RIVER BED IN SOUTHERN BOLIVIA

In these desert regions, devoid of trees, the run-off after the occasional heavy rains is rapid and floods pass through the valley with a roaring front 3 or 4 feet high, dangerous to travelers on the highway that uses the stream bed.

do with us, or Chimborazo and Cotopaxi in Ecuador. The view as the sun sets is especially striking, the glistening white passing into pink and purple and finally fading to a shadow. Another high mountain, Sorata or Illampu (6,645 meters) lies about 50 miles north of La Paz, but can not be seen from the city.

In the absence of our minister, Mr. Cottrell, the secretary of our legation, Mr. Flack, brought me in touch with many people who aided me very materially. In this he took special pains and added greatly to the success of my trip. Wishing to ascend one of the high mountains I chose Illimani as being most accessible and, in company with Mr. Dagg, went by mule to a ranch on the side of the mountain, the trip occupying two days. On the third day we ascended to about 16,000 feet where there is a large glacier with a

MT. ILLIMANI LOOKING EAST FROM LA PAZ
It is about 30 miles away but dominates the view all over this region. Altitude 6,619 meters (about 21,700 feet).

front about 100 feet high. On the fourth day we returned to La Paz.

I had been in correspondence with Dr. Otto Buchtien, the well-known German botanist, long resident in Bolivia, who was then in southern Peru. I was fortunate in having his company on my next trip which was to the Yungas, the montaña region lying to the north and east of La Paz over the eastern Cordillera. Sr. Aramayo, the director general of the Yungas railroad, aided very efficiently by furnishing passes for Dr. Buchtien and myself to Pongo and mules and a man for our trip through the Yungas. The railroad is completed northward over the pass at over 15,000 feet and on to Pongo at about 12,000 feet. Here we took mules, three for riding and one for cargo, consisting of my cot and bedding, a supply of supplementary food, and collecting outfit. We descended rapidly to the forested region and by many ups and downs through valleys and

YARETA

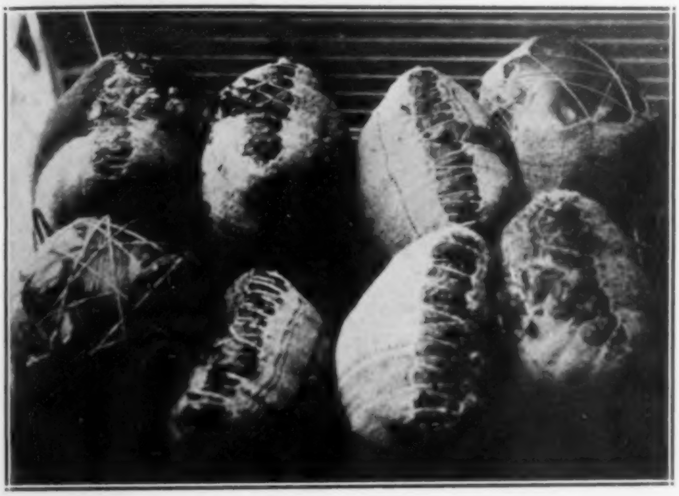
Fuel at a railway station on the puna. Many carloads piled here for shipment. The plant (*Azorella monantha*) is a tussock plant growing near snow line.

over ridges passed through San Felipe, La Florida and came to Chulumani, all in Sur-Yungas, the last city being the capital. Returning we crossed over into Nor-Yungas and went through Coripata, Coroico (the capital), Bella Vista and back to Pongo. Dr. Buchtien was widely acquainted in the region and we were able to stop at several plantations with his friends.

FUEL AT THE RAILWAY STATION

The wood is roots and gnarly stems of desert shrubs.

The trip was a hard one for ourselves and for the mules but I was surprised at the endurance of the animals. Seven days continually traveling, having no grain, nothing but alfalfa, corn leaves, cachi (*Axonopus scoparius*), or bamboo leaves, much climbing and descending 5,000 feet at a time, yet with no signs of collapse. I had my own saddle that I had brought from the states. The collecting was done as we traveled, that is, when I saw a grass that I wanted I dismounted and the helper brought the press, the plant was placed in papers and we proceeded thus, mounting and dismounting throughout the day. We succeeded in getting several species of bamboo in flower, which was good fortune as bamboos flower only occasionally.



Sacks of Coca Leaves on their way to Market
Cocaine is extracted from the leaves but the leaves themselves are chewed with paste of ashes, by the Indians, as a stimulant.

The Yungas is famous as one of the chief sources of coca, the plant from which cocaine is extracted. The plant is a shrub somewhat resembling privet. The leaves are gathered, dried and shipped to the sierra where they are extensively used by the Indians as a stimulant. For this purpose the leaves are mixed with a specially prepared paste of ashes, and chewed as is tobacco. Almost every Indian man may be seen with a bulge in one cheek showing the location of the quid. The alkali releases the alkaloid which allows the user to work with less food and with less fatigue than normal. The shrubs are grown on hillsides in carefully prepared ditches in terraces. Coca should not be confused with cacao, an entirely different plant from which chocolate is made.

DR. OTTO BUCHTIEN
The well-known German botanist, long resident in Bolivia. He is very familiar with Bolivian plants and has published a flora of the country.

A HOTEL IN THE YUNGAS
Dr. Otto Buchtien in the foreground.

After returning to La Paz, I made arrangements to go to the southern part of the country. A letter from Mr. Flack to Mr. Trueheart, assistant general manager of the Ulen Contracting Corporation in La Paz, interested his friendly aid in my work. The company is building the road from Uyuni to Villazon on the Argentine border, and regular trains run as far as Atocha. Construction

COCA PLANTATIONS IN THE YUNGAS
The shrubs are grown in carefully prepared terraced ditches. The whole country is dotted with these fields far upon the sides of the mountains.

trains run for several miles at each end of the remaining distance, but there is a long gap through which one must go by auto or by mule. Mr. Trueheart arranged to furnish transportation on construction trains and to provide a man and three mules for the intervening distance.

On the way to Atocha, I made a side trip from Oruro by rail to Cochabamba, the center of a rich agricultural valley. Mr. Wash-

burn, head of the American Institute, a school for boys and girls, aided me here. Cochabamba has a delightful climate and is a pleasant place to live, being at an altitude of about 8,500 feet.

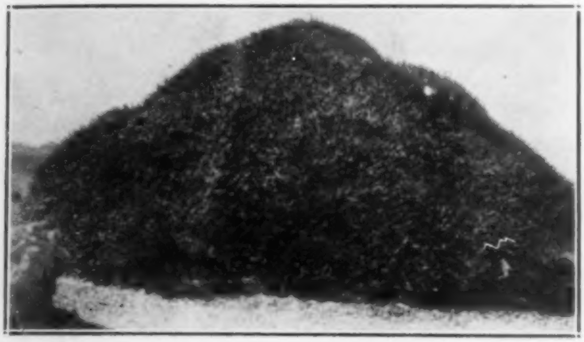
The southern part of Bolivia is arid and the xerophytic character of the flora is shown by the large number of cactuses. One large columnar species (*Trichocereus terscheckii*) is a timber tree, the woody ring being sawed into boards, these being used for the construction of floor, doors and partitions. The trip from Atocha to

A Common White-flowered Columnar Cactus near La Paz

the end of rails coming up from Villazon occupied three days. One cargo mule carried my cot, bedding and other baggage. I went on to Villazon and crossed over the line to La Quiaca in Argentina as there is a hotel at that place.

The road for fifty miles lies in the dry bed of the principal river of the region and passes through Tupiza, the capital of the province. Although dry most of the time, the valley is subject occasionally to heavy floods. Because of the lack of trees and sparseness of other

The Desert Plain at Uyuni, Southern Bolivia



A Large Tussock Cactus with Yellow Flowers

On the desert plain near Uyuni, southern Bolivia. The tussock is about 2 feet high.

Eroded Ridges between Illimani and La Paz

Xerophytic shrubs in the foreground.

vegetation, the run-off of the water from the surrounding hills is very rapid and the flood comes down the bed of the river as a wall three or four feet high, and travelers must scurry to the higher land for safety, warned by the sound before the water is seen.

Returning to Atocha and Uyuni, I went out by the way of Antofagasta, Chile. There are now three ways of getting to La Paz by rail, Mollendo through southern Peru, and crossing Lake Titicaca, as previously described; Arica through the disputed province of Tacna; and Antofagasta to Uyuni as

THE CARDON, A COLUMNAR CACTUS
Common in southern Bolivia. Boards for building purposes are made from the woody ring. This stem is about a foot in diameter.

A WOOLLY-TIPPED COLUMNAR CACTUS

just mentioned. When the road is finished from Atocha to La Quiaca there will be direct communication by rail from Buenos Aires to La Paz.

The southwestern part of Bolivia through which our train passed is very arid with much alkali, what is often called in

GORGE ON THE WAY TO TUPIZA, SOUTHERN BOLIVIA

LLAMAS AT ATOCHA, SOUTHERN BOLIVIA

our Great Basin region by the colloquial name slick desert. There is produced here much borax, salt and other minerals. The whole interior of western Bolivia is a great plateau, much of it 12,000 to 14,000 feet altitude. The valleys, especially toward the east and south, are rich agricultural irrigated regions.

The botanical results were of great interest and will ultimately appear as an account of the grasses of Ecuador, Peru and Bolivia, but are rather too technical for the general reader. I did not have time to go into the Beni, the tropical country to the north, lying in the Amazon Valley. Our knowledge of the flora of this region depends largely on the collections made by Dr. Rusby, of Columbia University, and his assistants, including Miquel Bang, and the staff

LLAMAS AT REST, ATOCHA

ONE OF THE GLACIERS ON ILLIMANI AT ABOUT 16,000 FEET

of the recent Mulford Expedition. This northern area was formerly a great rubber-producing district, but the rubber industry in all South America has been injured by the product from the plantations in Malaysia.

THE PHYSICAL BASIS OF DISEASE

By THE RESEARCH WORKER

STANFORD UNIVERSITY

VII. CURATIVE FORCES OF THE HUMAN BODY

1

"Now we've entered your state," said the manufacturer, as the Overland Limited was descending the western slope of the Sierras the next morning, "you'll probably want to spend your time boosting California."

"I'm not a 'Native Son,' " replied the research worker.

"Congenital Californians are objectionable," said the lawyer. "But, were you ever at the mercy of a native Texan?"

"The worst bore of them all," said the manufacturer, "is the booster of 'Little Ol'N'Yawk,' ignorant of everything west of the baby bluffs he calls the 'Glorious Palisades.' "

"We've taken up the main causes of human disease," said the research worker. "Congenital defects, tissue degeneration, tissue death, tissue overgrowth, accumulations of fluid, abnormal chemical reactions, psychical perversions. Let's take up as our topic the various curative mechanisms of the human body, forces tending to prevent or to overcome disease. The human body is really a wonderful structure. Adequate factors of safety, marvelous powers of readjustment and self-repair."

"What percentage of diseases will get well without treatment?" asked the lawyer.

"Impossible to say. Many diseases are self-limiting, full restoration of the body to its original power and efficiency without treatment. With most diseases, however, recovery is only partial without medical aid. There is some permanent loss of capacity or efficiency. Only a small percentage of human diseases are incurable without medical or surgical treatment."

2

"One of the important defenses of the human body is the reserve capacity of vital organs. The major part of almost any organ can be removed surgically or destroyed by disease, and the organ will still be able to perform its necessary work—two thirds of the kidneys, half of the lungs, three quarters of the liver. Or

degenerative processes may attack an organ as a whole, reducing the power of its individual cells by half, even by two thirds and the organs still be competent to meet ordinary demands. Such an organ, however, may be incapable of meeting emergency demands.

"Not only is there this large reserve capacity of individual organs, but there are examples of duplication of function in different organs. Certain organs may be completely destroyed by disease with other organs capable of performing their necessary work. In rats, for example, the adrenal glands may be completely removed. Certain cells in other tissues will perform the necessary work. The adrenal glands or their equivalent, as you know, are necessary for life."

3

"Another valuable defense is the growth potentiality of vital organs. You are familiar with growth potentiality in muscles. By proper exercise the muscles increase in size and strength. Exactly the same growth potentiality exists in vital organs. If the aortic opening from the heart, for example, is narrowed by tissue overgrowth, increasing the resistance to the forward passage of blood, the increased work necessary to keep up a normal circulation stimulates the heart muscle to growth. The heart walls may become two or three times their normal thickness and strength. The reserve capacity of such a heart may be nearly equal to that of a normal heart."

"Is that what's meant by 'compensation'?" asked the manufacturer. "The doctor said my nephew would be all right as soon as his heart was 'compensated.' "

"The process is known technically as 'compensatory hypertrophy' or compensatory growth—increase in size and strength counterbalancing the increased resistance to blood flow. Compensatory growth is common to all organs and tissues. If one kidney of a dog is removed the remaining kidney will almost double in size within four or five weeks. This is a common surgical exercise for medical students. The major part of the liver may be destroyed and the liver restored to its normal size by growth of the remaining parts. It is not uncommon in rabbits, for example, to find all but one lobe of the liver absent or destroyed, with the single uninjured lobe as large as an entire normal liver.

"Compensatory growth of uninjured portions tends to restore a vital organ to its original reserve capacity. The restoraton is rarely complete, however. There is usually some permanent loss of ability to meet emergency demands. Certain organs even have

almost no growth potentiality. This is true of the brain. Destruction of one part of the brain causes no compensatory growth of the remaining parts.

"There are limits to this growth potentiality in all organs. If too large a part of an organ is destroyed by disease, the remaining parts may be so exhausted by overwork that compensatory growth does not take place. The uninjured parts may even degenerate or shrink as a result of this overwork.

"Can you stimulate this compensatory growth?" asked the lawyer.

"There is no known drug that will directly stimulate the compensatory growth of vital organs. Indirectly, the growth may sometimes be hastened by decreasing the necessary strain on the organ. Rest in bed, proper diet, elimination of waste products will sometimes reduce the necessary strain so that compensatory growth takes place. One of our valuable assets in this connection is our sense of fatigue. Reduced capacity in almost any organ may show itself in increased consciousness of fatigue. This tends to force the individual to adopt a mode of life consistent with the reduced capacity of the organ."

4

"There are equally important defenses not dependent upon the size and growth potentiality of vital organs, but dependent upon chemical factors. One of the most important of these is the food reserve or emergency rations in the body. You are familiar with the store of predigested and prepared fat that may be used as food in times of starvation or emergency. There is a similar store of predigested and prepared starches and sugars. By means of this store the percentage of sugar is kept fairly constant in the blood, even though no sugar or starch is taken as food. The blood, as you know, contains about one tenth per cent. sugar. A pound of predigested sugar is stored in certain tissues, particularly in the liver. Emergency supplies of other foods also exist.

"One of the most important emergency substances is the emergency supply of alkalies. Many of the commoner poisons formed by putrefactive or degenerative processes in the body or introduced from without are acids. A trace of free acid, as you probably know, will kill tissues. The emergency alkalies promptly neutralize these acids before they reach vital parts. Several ounces of vinegar, for example, must be injected into the blood stream of a dog before the reserve alkalies are used up.

"Equally important chemical defenses exist against other common poisons. Carbolic acid, as you know, is constantly being

formed in small amounts by putrefactive processes in the intestines. Carbolic acid is quickly rendered non-toxic by chemical defenses. Very adequate defenses exist against all the commoner poisons."

"What about eating yeast to stop intestinal putrefaction?" asked the manufacturer. "The papers are full of it."

"The advertisements I've seen have advocated yeast solely as a source of vitamins. There are certain chemical substances in green plants that are necessary foods. Scurvy, rickets or other partial starvation diseases may develop if one is deprived of these substances. There is an overabundance of vitamins, however, in ordinary diet. Milk, butter, lettuce, tomatoes, oranges are particularly rich in vitamins. Yeast also contains vitamins. If you prefer a yeast cake to a salad or a glass of milk, I see no reason why you shouldn't eat yeast."

"But the papers say yeast cures disease," insisted the manufacturer.

"The advertisements I've seen have been very cautiously worded. A rat on a vitamin-free diet has a stunted growth. Add yeast to his diet and he will grow. The advertisements don't say, however, that if you add any other source of vitamins, such as milk, tomatoes, lettuce, alfalfa, the rat will grow equally well, even better. The ignorant reader, of course, may imply that yeast is a cure-all."

"Clever sales method," said the manufacturer.

"But rotten business ethics. How about the ignorant consumptive who wastes valuable months eating yeast that should be spent in a sanitarium? Or the cancer that reaches an inoperable stage while the woman eats yeast?"

5

"Besides adequate chemical defenses against the commoner poisons there is a remarkable chemical potentiality against unusual poisons. Take morphine. The normal individual has a very rudimentary defense against morphine. Morphine is destroyed very slowly in his tissues. A morphine addict, however, rapidly destroys relatively large quantities of morphine.

"A better illustration is furnished by toadstool poison. The body has very rudimentary chemical defenses against this substance. A small quantity causes death. An animal, however, that is given repeated minute doses of toadstool poison rapidly develops his rudimentary defenses. Within a few weeks the animal can be given a hundred times the usual fatal dose of toadstool poison without apparent symptoms.

"This acquired resistance to toadstool poison has been carefully studied. Part at least of this defense depends upon chemical changes in the blood. A small amount of blood from a resistant animal, mixed with toadstool poison, will render the poison harmless. The mixture may be safely taken by normal animals. Even the clear serum or liquid portion of the blood has this poison-destroying or poison-neutralizing power."

"Is that serum ever used?" asked the manufacturer.

"The number of cases of toadstool poisoning is too small for such a serum to be commercially profitable. I am not aware that it has ever been tried with human beings. The popular fear of toadstools is an adequate protection. A somewhat similar serum, however, prepared by stimulating the rudimentary defenses against snake venom, has been tried. This serum has distinct curative effects if administered promptly after snake bite.

"The most important applications of such sera, however, are against infectious diseases. In diphtheria, for example, the usual death-rate of 40 per cent. has been cut down to less than 2 per cent. by anti-diphtheritic serum, a saving of life that can be effected in no other way. Unfortunately, sera have been found of no value in the majority of infectious diseases. Take tuberculosis, for example. Thousands of attempts have been made to produce a curative serum, thus far with no success. The essential chemical defenses against tuberculosis apparently do not exist in usable quantities in the blood. The essential defense is presumably located in some other part of the body. Just where, is unknown."

"Why don't you get on the job?" said the manufacturer. "Locate this defense."

"This problem is typical of numerous research problems now waiting solution. The average university research worker hasn't the equipment, technical assistance, leisure or funds for such work. The most he can do is to content himself with some minor, often unimportant, phase of such a problem."

"I should think the regents of any university would sell their shirts to make possible such research," said the lawyer.

"As soon as the importance of such work is realized by the general public, adequate support will undoubtedly be provided."

6

"Although sera have been found valueless in the majority of infectious diseases, other methods of using our rudimentary defenses have in some cases been successful. If toadstool poison were much more common, toadstool fragments being a frequent

contamination of daily food, it would probably be possible to protect an individual against this danger by developing his rudimentary defenses—repeated administration of minute doses of toadstool poison. Whether or not this would be effective one can not say. The defense might never become sufficiently high with human beings to protect against the ordinary accidental dose of toadstool poison. The defense might not be sufficiently lasting to be worth while. It is, however, possible that a very effective defense might be developed, after the administration of only two or three minute doses of toadstool poison, a defense lasting a lifetime.

"This method of stimulating our rudimentary or potential chemical defenses has been successful in a number of infectious diseases. The death-rate from smallpox, for example, has been reduced fully 99 per cent. by vaccination. Typhoid fever was almost eliminated from the army. A number of veterinary diseases have been controlled."

"Why is there such a violent objection to vaccination?" asked the manufacturer.

"The objection is mainly psychological—infantile resistance to authority, a prominent characteristic of childhood. With a few, however, there is a real objection due to religious belief."

"I have a neighbor of that kind," said the lawyer. "Retired minister. Divides his time equally between denouncing vaccination because it 'defeats the purpose of the Almighty,' and taking pills to assist the Almighty in relieving his constipation."

"Unfortunately this method of stimulating the rudimentary defenses has been found of no value in the majority of infectious diseases. Tuberculosis and syphilis are examples. In neither disease can the rudimentary defense be sufficiently increased by vaccination to afford any degree of protection. A successful method of anti-tuberculous vaccination, however, has been found for cattle."

"Then we may expect, in time, a successful method for human beings," said the lawyer.

"I am not so certain of that. The rudimentary defenses of cattle against tuberculosis are much more efficient than those of human beings.

"Development of the rudimentary chemical defenses is the main way in which the body automatically overcomes infectious disease. Within a few days after receiving an infection the rudimentary chemical defenses are often sufficiently increased to kill the invading micro-organisms or to render them harmless. This automatically increased chemical defense is occasionally permanent, lasting a lifetime. It is often transient, however, disappearing within a

few days or weeks. Gonorrhea, for example, even when spontaneously cured, leaves behind it no increased resistance to reinfection."

7

"Can you hasten the development of these defenses?" asked the manufacturer.

"Direct stimulation of the potential chemical defenses by therapeutic agents is a research goal for the future. We are too ignorant at present of the physiological mechanism of these defenses to make direct stimulation possible. Physicians must rely on indirect methods."

"Osteops claim they can do it," said the lawyer.

"Massage is a valuable therapeutic agent. It's used by all schools of medicine. It is particularly valuable for its psychical effects. There is no evidence, however, that massage in any of its forms will directly hasten the development of our potential chemical defenses. I doubt if osteopathic physicians make such a claim. It is easy to misunderstand their figurative language."

"How about Christian Science?" asked the manufacturer.

"There is no experimental or statistical evidence that the development of the rudimentary chemical defenses can be directly assisted by any form of religio-therapy. The blood of the most ardent Christian Scientist will not render toadstool poison harmless for an experimental animal. Nor will his tissues or body fluids kill and digest more germs of syphilis than those of the average individual. The death-rate from influenza among Christian Scientists is the same as that among his irreligious neighbors. Remember, we are not dealing here with subjective sensations, the psychical side of human disease."

"Then you do claim there's no God," said the lawyer.

"My statements were statements of biological facts. They are not inconsistent with any conception of Deity with which I am familiar.

"The two groups of defenses we have considered: first, the reserve strength and growth potentiality of vital organs, second, the chemical reserves and chemical potentialities, are the two most important groups in the human body. There are a number of valuable minor defenses, however. Among these are—

"Brush y' off, suh?" said the porter.

"Sorry to break up the party," said the lawyer, "but I get off at Sacramento."

RELIGION AS A FACTOR IN HUMAN EVOLUTION

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PERFECT men in a perfect environment is the final aim of all human endeavor. But we are facing a dilemma. One of the many attributes of the perfect man is that he should grasp all truth. Present-day knowledge is but a small fraction of the total truth, discovered and undiscovered, and there are few if any men who have either the training or the mental capacity to master completely and in detail even two or three of the departments of knowledge out of the scores of departments in which modern research is rapidly increasing the total human knowledge. Furthermore man can not be trained or educated up to such a point. Heredity will not permit it, but, pointing now here, now there, it says to each man, "Thus far, and no further, shalt thou go." Thus is man limited, not only in this, but all other attributes of perfection, such as bodily perfection, resistance to disease, moral beauty and ideal temperament. There is a religion which bids man to be perfect, and tells him that the first and most important thing for him to seek is the kingdom of God and His righteousness; and this kingdom and this righteousness imply nothing less than a perfect race of men in a perfect environment. This is just what we stated at the outset to be the final aim of all human endeavor.

Historians and psychologists have told us much about the origin of religion and its effects upon man in the past. It would be interesting to run over the leading facts and theories, if such were possible within the space of this article, and at the same time give an epitome of the whole of human evolution to the present day—a thing no mortal yet can do—but it is my purpose here to confine attention to what is equally interesting and far more important: man's *future* evolution as it may be affected by the religion factor. The past of evolution is always interesting, chiefly so because of the light it throws upon the course and method of evolution in general, and what we may expect in future.

Several keys must be applied simultaneously if we would unlock the safe-deposit drawer which guards the future perfect men. Heredity is one of the indispensable keys, as are also ideal training and ideal surroundings. The result will be perfect men in a perfect environment. A certain religious factor is, however, essential

to each one of the three keys just mentioned—heredity, training, surroundings. But there are at least two classes of people who can see no logical place for religion: first, those who have had little or no religious training or experience, and who therefore can not be expected to see anything in it; and secondly, the many who have been unfortunate, in one way or another, in the religious experience they have had, and therefore shun it. Some would add to these two other classes: thirdly, those whose heredity omits entirely religious sentiment, and fourthly, those who, as followers or admirers of some in one of the first three classes, take their word for it that there is no logical place for religion in an enlightened world. Right here we may well focus on our dilemma mentioned at the outset—a world full of knowledge which is only a fraction of the sum total of truth, discovered and undiscovered, also full of people of varying capacities to grasp limited portions of said fraction, and, furthermore, able to measure up to only a part of each of the other characters or attributes of perfect men. The religious deficiencies just mentioned become inextricably confused with the mass of other deficiencies. The perfect men must be produced, and the surroundings must be perfected; how are we to proceed?

At once there come to mind schemes to educate the world of mankind in the principles of eugenics, that they may apply these in their home life as well as in their selection of mates. More radical plans, breaking up more or less completely the long-sanctioned home ties, have been proposed. Numerous social or religious colonies have been founded with a view to bring utopia or revive the golden age. One system of education has criticized and supplanted another toward this end. One religious denomination after another has arisen to point out the weaknesses of other systems, and bring the perfect creed or practice. Men have even gone to war to reduce slavery or to make the world safe. But the old world remains very imperfect and man very far from his goal. Man has greatly multiplied the *things* which he possesses, and his knowledge has far outstripped his individual capacity to absorb it. His heredity appears to remain about the same as yesterday or a bit lowered through his own interference with nature's processes for eliminating the weak and the mentally unfit and the emotionally unfit. These two latter classes, comprising most of the criminals, were doubtless quietly put out of existence by their fellows of more barbarous or savage days. So much for our present heredity. As to our surroundings, we are indeed learning some things about bettering this world, improving its fruits, vegetables, grains and domestic animals; inventing labor-saving devices, means of transportation and communication; yet much of our labor saved was first brought about by the things and circumstances which we ourselves had

made, while in many other respects we have marred the beauties of nature and polluted the air and the waters. The chief difficulty in educating all mankind to the point of practicing eugenics would lie in inducing people with such limited minds as the average man possesses to want to try it. It could be properly planned and would work very well if they would all be willing to apply the fundamental principles. A group of geneticists to-day could very easily draw up a brief and simple statement of the natural laws underlying race-improvement, in such form that all possessing average intelligence could understand and follow if they would. But how many would follow them? The least fit, upon whom the restrictions would fall most heavily, would be the least apt to submit. Another constitutional amendment, of world-wide application, would be required to control them. And yet it pays to meditate upon such plans, for a way may yet be found to uplift the human race as a whole.

A plan in which more immediate hope would seem to lie is suggested partly in the famous Hebrew historical literature and partly in the record of rocks, which reveals something of the story of the succession of creatures which lived in the past. We may call this the New Abraham Plan. Paleontology shows us that single individuals, or single pairs, have been the starters of new species, rather than great masses of individuals. The plan which was laid down for Abraham, and conceived by him, would have produced a new species of superior human beings if it had been consistently and unfailingly carried out. Even as it is, with all their breeches of the original sacred plan, the Jews are a remarkable people, decidedly distinctive in many ways, if not altogether in the ways originally planned. They came very near to producing a new and distinct human species, and although they fell short, they have pointed the way in which it can be done. Any one may deliberately determine that he will be a new Abraham, and that he, and his family after him, shall establish a new race, superior in every respect. If this man's predetermined principles were as lofty and as pure as those laid down for the Hebrews, and if they were consistently carried out by his offspring, under pain of expulsion, the result would be very marked, and, I believe, surprisingly speedy. This human race is more primitive and plastic than people generally suppose. The great masses of the people labor under the delusion that we are inextricably fixed in a rut—that as we are now, so we always have been and always shall be. But one of the hopeful things which zoology points out about our race is that it is not yet so highly specialized as not to be able to change and continue changing.

The plan proposed for Abraham and his descendants involved pure line breeding, with careful selection of mates, and a code of ethics highly moral, sanitary and religious. The intense faith in the guiding supervision of God, the Creator of all things, was a support without which the plan never would have been carried out to such an extent and during so long a period of time. Man is essentially a religious creature and can do things with the aid of religious fervor and faith in which he never would persist without such religious impelling force. It is bred in the "bone," and is as much to be taken into account as his appetite, affections and intelligence. In the Hebrew historical account we read that God said to Abraham "I will make of thee a great nation, and I will bless thee, and make thy name great; and thou shalt be a blessing: and I will bless them that bless thee, and curse him that curseth thee: and in thee shall all families of the earth be blessed. . . . I am the Almighty God; walk before me, and be thou perfect. And I will make my covenant between Me and thee." The conviction of such a covenant as this was a strong, guiding force in the life of a man like Abraham. When it came time for his son Isaac to wed, Abraham would not consider his marrying any of the Canaanites close around them, but insisted that a trusted servant go far back "unto my country, and to my kindred, and take a wife unto my son Isaac." Divine guidance was also sought in the selection of the relative who was to be Isaac's mate. And this same mate was later very careful concerning the mate for her own son Jacob, for we read: "And Rebekah said unto Isaac, I am weary of my life because of the daughters of Heth: if Jacob take a wife of the daughters of Heth, such as these which are the daughters of the land, what good shall my life do me?" Isaac thereupon commanded Jacob to go back to the old ancestral stamping ground, and find a cousin to marry. And always there was the religious conviction of the presence and guidance of God through this eugenic scheme.

In spite of many individual errors, shortcomings and even failures, many very capable and brilliant men were produced from this stock, such as Joseph, David, Solomon, Daniel, Isaiah, Jesus and Paul, some of whom were remarkably pure in their moral strength, while others showed weak traits along with their very eminent qualities, for the whole scheme had not provided sufficient weeding-out of the morally weak or dishonest. Such undesirables, together with all backsliders, should have been promptly sent out of the community and merged in the Canaanites. What wonderful beings David and Solomon would have been, if they had been as consistently pure in heart and as consecrated as Joseph, Daniel and Jesus. It remained for the latter to embody all wisdom and virtue and faith.

The forerunner of Jesus saw the need of more housecleaning in the whole eugenic scheme, and clearly stated the principle of the axe and the fan, a principle which many weaker-kneed followers can not bear. He believed one wasted his time in pruning a tree or a man with bad heredity. Not the pruning-hook but the axe is needed, and that to be applied right at the root. There was no place for the man or the tree which would not bear good fruit. Similarly the fan was to separate the bad from the good. The bad tree and the chaff alike were to be promptly and completely destroyed, as by fire; the good trees cared for and the wheat gathered into the garner. Our social work of to-day is doing undeniable good, but also much good time and effort is wasted trying to prune human "thorns" into "fir trees" and human "briers" into "myrtle trees." Long before the days of John the Baptist, Isaiah had sensed the hereditary principle, and prophesied: "*Instead of* the thorn shall come up the fir tree, and *instead of* the brier shall come up the myrtle tree." Recognizing the same principle, Jesus later said, "Ye shall know them by their fruits. Do men gather grapes of thorns or figs of thistles? A good tree can not bring forth evil fruit, neither can a corrupt tree bring forth good fruit. Every tree that bringeth not forth good fruit is hewn down and cast into the fire." This is directly in accord with the forerunner's famous principle of the axe and the fan, "And now also the *axe* is laid unto the *root* of the trees: therefore every tree which bringeth not forth good fruit is hewn down, and cast into the fire." Referring to Jesus, the forerunner says, "whose *fan* is in his hand, and he will thoroughly purge his floor, and gather his wheat into the garner; but he will *burn up* the chaff with unquenchable fire." This can not possibly be made to mean everlasting punishment; it is, however, very good eugenics. Whatever destruction there is is very prompt and effective. The innately bad is separated and *burned up*. If there be anything of the doctrine of divine election in this eugenic principle, it is very simple and intelligible. Those who find this teaching of Jesus and his forerunner hard to understand either fail to grasp its simple truth, or fail to see the beneficent healing in the mildly bitter dose. Segregation and consequent elimination of undesirables of every class is one of the most helpful measures applicable to our race. Jesus also had no use for foolish people, as shown in his parable of the foolish virgins, nor for faithless folk, as shown in his condemnation of Pharisees. By eliminating every class of undesirable the race is rid of its heaviest handicaps, and is able to progress on its upward road unburdened.

From the birth of Abraham to the giving of the Ten Commandments about five centuries passed. Therefore five centuries before the giving of the Ten Commandments we find a man with surpris-

ingly high moral purpose for his times and an even much more surprising clarity of vision and mental acumen. From the call of Abraham to Joseph's Egyptian experience was about two centuries. In this short time we find a direct descendant of Abraham more highly developed morally and with as good or better mentality and vision and faith. Joseph was nearly three centuries before the time of the Ten Commandments. Five centuries after the Ten Commandments King Solomon, world-famed for his wisdom, is ruling over the offspring of Abraham. His educational advantages were vastly greater than had been those of his illustrious ancestors of ten centuries back, and these, together with his superb mind and other God-given, hereditary qualities, made him a type for wisdom, glory and power through succeeding ages, so much so that many of the descendants of Abraham looked back to the reign of Solomon with wistful longing. But we have a right to expect more moral strength and a higher code of ethics five centuries after the Commandments and eight centuries after Joseph. The Israelites had not been faithful to their long-guiding principles; they had mingled with their surrounding neighbors of lower ideals and inferior lineage; had even taken such into their midst and merged them with themselves; had not strictly kept the Ten Commandments given them nor winnowed out from their midst the black sheep or backsliders, who would not or could not be faithful to their code and live the clean, noble life of wisdom and faith and observe the care in the choice of a mate, thus following the example and precepts of the wisest of their forefathers.

If from Abraham to Solomon this purity had gone hand in hand with the winnowing process during all the ten centuries of time, a far more wonderful heart and mind and personality would have been born into Solomon. He would have been arrayed more gloriously than the lilies of the field, not less so.

Between the reign of Solomon and the ministry of Jesus another ten centuries elapsed, and we find at last a man possessing all the excellencies of an Abraham, a Joseph, a Daniel and a Solomon, with none of their deficiencies, but many added virtues, shining bright in the glory of the Father, the All-Great Creator. At last the plan of Abraham and the plan of the Ten Commandments showed full fruition in one man among the millions. And he taught the imminence of the kingdom of heaven. That all-perfect environment, peopled with its all-perfect men, was right at hand where we may grasp it, if we but exert ourselves bodily and mentally to that end. If we let the principles of the axe and the fan and the Ten Commandments and the Golden Rule and the Sermon on the Mount have full sway in our personal life, our social life and our corporate life, which includes both our business organizations and our polit-

ical and national organizations, then indeed would the ideal men in the ideal environment soon be here upon earth to stay as long as life lasts on this sphere. The Kingdom of Heaven would be upon earth.

The genetic principle of selection and rejection, which some holy fathers have seen through a glass darkly in the form of a doctrine of divine election, and which we, using the symbolism of John the Baptist and of Jesus, may well call the principle of the axe and the fan, was foreshadowed in the plan of Abraham. Abraham and Joseph and the great prophets of Israel were men of vision. Their Maker revealed to them fundamental truths of Nature. They saw, as it were in a vision, certain underlying laws of life. How sharply some of these men drew the lines; and how hotly some of the prophets upbraided the people for their waywardness and their folly! And in more recent times, a holy monk and a teacher of youth, named Mendel, experimenting scientifically in his garden laboratory, revealed by scientific method, to the world of modern investigators, the way which is rapidly leading to an understanding of the basic principles of heredity and to a comprehension of its inevitable importance.

To-day in the city of Cincinnati there is a man of vision named Nash, a manufacturer of men's clothing, who, sensing that the Golden Rule is the divine law governing human relationships, incorporated it into his business in 1917, with apparently miraculous results in the years which have followed. These results affected the business, the employees and himself, with remarkable benefit to all, both in times of adversity and time of prosperity. From several years' experience Mr. Nash is convinced that the Golden Rule is "the only infallible, workable industrial and economic law." Many men of vision in the past have glimpsed portions of the truth, but few have actually incorporated such a vital truth into modern business on such a grand scale and in such a vital manner. Nash has shown the world that there is a vast difference between letting every one tacitly accept the theory of the Golden Rule and actually making it the fundamental rule of a business employing thousands of persons. Any new hand coming in to such a business, though he may never have heard of the Golden Rule before, soon realizes that he is surrounded by its atmosphere and becomes influenced by it as by a force which he can not resist.

But the Golden Rule is only a small fragment of the Sermon on the Mount. It is found in the twelfth verse of the seventh chapter of the gospel of Matthew, while the Sermon on the Mount fills the fifth, sixth and seventh chapters of Matthew. And I believe that in order to be able to apply the Golden Rule one must know more than the Golden Rule, in fact be thoroughly steeped in all the basic

principles of the Sermon on the Mount, besides being thoroughly the master of his own business in which he would apply it.

Now, into what sort of beings would we have this race of ours evolve? Creation is but an ugly mess if we are to remain as limited in intelligence, as cramped in mental capacity, as faulty physically, and as ordinary and joyless in personality as we are at present. God would have done but a bungling job in making man if we can not become innately vastly superior to what we are. Even the best men this world to-day can show are little more than puppets, jokes or suggestions of what men should be.

One thing is certain, the man of the future, when perfected, must be a tremendously joyous individual;—none of your mechanistically developed, shrewd, coldly calculating brains, requiring that all be done for him by machinery, while he thinks, and just thinks, and then thinks again, with perfect precision, accurately and unfailingly. Neither is it desirable that he become just a cog in some vast social organization. He must always be individualistic, and should remain sufficiently primitive to be able to get his own food from nature by his efforts. The sequence of living forms throughout the dim corridors of the past, as shown in the fossil record of the rocks, points out too clearly the dangers in too high a degree of specialization. Our brains, even in their present stage of development, are continually tempting us to neglect our bodies and depend solely upon the cleverness of our minds for our life and sustenance. A certain measure of physical degeneration in consequence of this is manifesting itself fairly generally to-day. We want our bodies to be stronger and more generally beautiful in form than they are to-day. We want them to be thoroughly resistant to all diseases, a hereditary quality to be borne in mind by our new Abraham and his successors in their choice of mates, as also in their expulsions from the clan or restrictions within the clan. Many important methods are being pursued in the prevention of disease and in rendering man more resistant to various diseases. The most desirable of all these methods would be to be born absolutely immune to disease. Hereditary immunity is better than resistance, either acquired or hereditary.

Our perfect man of the future, then, should be a highly joyous individual, with far greater mental capacity than any man now possesses, a strong, quick and well-formed body, immune to disease. What *else* does he need?

In order to attain that degree of joyousness, and the mental and physical perfection which are essential to the joy, he requires the truest type of religion which heaven or earth can yield. Startle not at the word *religion,* at which many conjure up mental pictures varying greatly from the fundamental religion of Nature, which

pervades all the Universe! Our new Abrahams, if any wish to be such, must have *vision*—mental and spiritual vision or faith as it is often called, and they must have a law or code by which to go, for all nature has its laws. And the world has not seen a better code of ethics than that given by Jesus in the Sermon on the Mount nor a better faith than that perfectly natural faith which we find in Abraham and in Joseph, Moses, Daniel and developed to its highest degree in Jesus.

All things in nature have a physical and chemical basis, but pure physics and chemistry, raised to the nth degree in the evolution of the finished man of the future, would leave him a cold, joyless and unenviable mental and physical machine at most. We may define religion as all that which, added to pure physics and chemistry, would make the men of the future radiantly beautiful, joyously creative and give them the highest degree of moral and spiritual vision. This definition of religion is a very different one from what comes to the minds of many, but when carried through, it implies the strongest and most abiding faith in God, and in Jesus, the Savior and the giver of the perfect code, the Sermon on the Mount, which embodies the combination of eugenics and Christianity necessary to guide the life of any who would be a new Abraham through whose coming generations the people of the earth would be blessed.

Any one, of any race, may be an Abraham, who has the vision and faith in the Great Guiding Power and the requisite moral, mental and physical virtues, and the clear and distinct laws by which to guide his conduct and the conduct of all his growing clan. His clan would in time, by sheer superiority, o'ertop all other peoples of the earth in every desirable aspect. Whatever of beauty he found, in mountain or flower or stream or sunrise or star or living being would be his by right and would enter into the personality of his people. The Kingdom of God and His righteousness would be his world in which he lived while on earth and his heaven after death. In the light of God he would see light and in an earth made over new he would prepare for heaven, be it in some far-off universe, or be it everywhere, as God is everywhere, or be it both.

The plan of Abraham is as simple as nature itself, whose deepest laws it involves; and it is as sure as physics and chemistry through which God works, for any who will consistently follow it through the generations, a thing which the descendents of the old Abraham have done but faultily, very faultily. It is equally the plan of Jesus, the plan of nature, and the plan of the Kingdom of God and His righteousness. It leads to ideal men in ideal surroundings, men and surroundings of a beauty and lustre and brilliancy and joy and wisdom beyond our highest conceptions.

SEASONAL PREVALENCE OF DISEASE

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Periodicity is one of the interesting phenomena in epidemiology, and a more searching study of the causes of the cyclic tendency of disease discloses fundamental factors of vital importance. A number of the communicable infections tend to periodic recurrence, but very few diseases recur with sufficient regularity to predict their reappearance with any degree of certainty. Prophecy is a test of the soundness of science. Furthermore, to be able to foretell gives opportunity for preparedness and prevention.

We know that another pandemic of influenza will some day sweep the world, but we can not tell when this plague may recur. The intervals between pandemics have been quite irregularly spaced. Brownlee, however, has pointed out that after a pandemic of influenza, recurring waves appear at intervals of thirty-three weeks, provided the thirty-third week does not fall between June and December; if so, the recurring waves appear in multiples of thirty-three weeks, in other words, avoiding the warmer months of the year. This sequence was largely true following the last two great pandemics, 1889–1890 and 1918–1919.

Measles is an example of a disease that recurs cyclically and with considerable regularity. In endemic regions, epidemic exacerbations recur every two or three years. In large cities, the interval is usually two years, and in smaller communities, three years. The explanation of this rapid tempo in the recurring beats of measles appears to depend upon the accumulation of a new crop of susceptible children.

Infantile paralysis in Massachusetts displays a sort of regularity in the tendency to an excessive prevalence about every fourth season. These epidemic recurrences are followed by a gradual decline until the next period, as shown by the following figures:

Year	No. of Cases
1909	923
1910	845
1911	260
1912	169
1913	361
1914	151
1915	135

Year	No. of Cases
1916	1,926
1917	174
1918	99
1919	66
1920	696
1921	233
1922	217
1923	221

A study of these figures shows clearly the tendency of infantile paralysis to occur in periodic phases or pulses in Massachusetts. It seems curious that this same periodicity is not evident in other places and therefore does not appear to be a general rule. The Massachusetts figures, then, may be only a coincidence, although they indicate a definite tendency which appears to be part of the natural history of the disease in this state. Despite the vagaries and uncertainties of infantile paralysis, we know that as long as the disease prevails there will be more of it in the summertime than during the cold season. We can forecast its tendency to seasonal prevalence, but we can not tell how much of the disease will occur. In other words, while we can prophesy the nature of the curve, we can not forecast its magnitude. The amount of infantile paralysis is capricious and depends upon variables, which will be discussed under the causes of seasonal prevalence.

A good instance of the uncertain way in which epidemic diseases recur is shown by the visitations of plague in London from 1563 to 1680. In 1563, an epidemic causing 23,000 deaths was recorded. In 1603, London was visited by a severe epidemic. The disease then became quiescent and probably endemic for 22 years. Suddenly, in 1625, there was a devastating outbreak with upwards of 35,000 deaths. Following this, there was a long period of 40 years during which plague smouldered with two epidemic exacerbations, one in 1636 (10,400 deaths) and the other in 1647 (270 deaths). After 1647, the disease apparently disappeared, although in all probability it remained endemic, for it is easy to understand how occasional sporadic cases might be overlooked. In 1664–65 the Black Death in London carried off 68,596 of a population then numbering about 500,000. A graphic description of this epidemic is given by Defoe in "A Journal of the Plague Year." Numerous references to the disease will be found in Pepys's Diary. Benvenuto Cellini describes his own case in his autobiography. Plague is one of the diseases that stamped itself upon art, science and literature.

It is interesting and even instructive to speculate why bubonic plague in London became severely epidemic five separate times at irregular periods—1563, 1603, 1625, 1636 and 1665. Before plague can become epidemic, there must be a large number of complex variables in conjunction. We can not have an epidemic of plague without first having an epizootic in rats. At the same time, the fleas must be numerous and active and the opportunities for contact and transmission between rats, fleas and man must be close, frequent and favorable. When we realize that it is well-nigh impossible to cause an epizootic among animals in their wild state,[1] we can understand that a great number of factors determine the prevalence of the infection among the rat population. Furthermore, a severe epidemic of this sort leaves immune a large proportion of both rat and human population, so that another serious outbreak must await inflammable material. In view of the large number of factors and the number of complex variables that enter into an epidemic of plague, it would indeed be passing strange if a disease of this sort had any regularity in its periodic recurrences.

Plague is one of the diseases that profoundly affected the economic, political and social history of civilization. I happened to be in Stratford-on-Avon on July 11, 1914. I turned back the pages of the parish register 350 years, and found recorded on July 11, 1564, the death of one Olivarius Gunne, apprentice of Tomae Gather als Degge. Then followed this laconic statement—*Hic incipit pestis.* Up to this time, from three to five deaths (a month) were recorded in the parish register, but from July 11, 1564, the rate jumped as follows:

July 11–31	16	deaths
August	35	"
September	83	"
October	58	"
November	27	"
December	18	"
January	5	"

Two hundred forty-two deaths in six months is a heavy toll for the little vicarage of Stratford. Shakespeare was a baby three months old when the plague broke out. Judging from the names recorded, the infection swept away entire families. Fortunately not a Shakespeare is on the list. How much has mankind lost throughout the world's long history by the untimely death of genius on account of preventable infections!

[1] The failure to cause an epizootic among the rabbits of Australia is an illustration.

Another example of irregular periodicity is shown by the story of diphtheria epidemics in Boston, New York and Chicago. In Boston, diphtheria was epidemic in 1863–64, 1880–81, 1889–90 and 1894; in Chicago, in 1860–65, 1869–70, 1876–79–81, 1886–87 and 1890. Within recent years, such epidemic outbreaks have not taken place and the disease should never again be allowed to get out of hand.

Many other instances of the periodic recurrence of disease could be cited, but the burden of this paper is to discuss that form of periodicity which expresses itself in seasonal prevalence. Many diseases recur annually with the regularity of the perennials. Some endemic diseases are as constant as the evergreens; some are as sure as the thistles, daisies and goldenrod; some prefer the spring, others the autumn; some are like exotic plants that will not grow at all on our soil; and still others flourish only when imported.

Seasonal prevalence is one of the most characteristic and alluring studies in epidemiology. Many correlations are disclosed between climatic factors and the seasonal fluctuations of certain infections. These correlations do not prove causation; in fact, the more seasonal prevalence of disease is studied, the more mysterious do the causes become and the more complex the difficulties. There are many underlying influences which control seasonal prevalence other than the evident factors of weather and climate. The surface of knowledge has been only scratched—rewardful results await the searcher in this field; all of which adds zest to the pursuit.

The relation of season to disease clings tenaciously in common speech. "Catching cold" infers the influence of low temperature, and "summer complaint" connotes the effect of high temperature; "under the weather" implies the consequences of climate; the term "influenza" signifies a mysterious influence and even supernatural effect of our environment.

Many diseases have a seasonal curve of extraordinary regularity. They return year after year with the definiteness of the crops. However, seasonal prevalence of disease may to a certain extent be violated when a communicable infection is introduced into a virgin population. Thus, measles, influenza and smallpox do not always wait for cold weather when introduced into the South Sea Islands or into a concentration camp recruited from country districts. Susceptible material of this kind may catch fire and burn freely out of season. On the other hand, when certain of the contact diseases that prevail especially in the wintertime are introduced into the tropics, they have a tendency to die out. Scarlet fever has never gained a foothold in tropical countries, and measles and diphtheria do not become serious problems under a vertical sun. Contrariwise,

common colds, influenza, pneumonia and tuberculosis play havoc in warm and tropical lands, just as they do in temperate zones.

One must be unusually conservative in drawing conclusions concerning the incidence of disease in tropical countries, for morbidity and mortality records are imperfect enough at best in favored climes; they are particularly incomplete under tropical conditions. We are therefore thrown back upon personal experience and impressions: the former is limited and the latter may be misleading. I well remember some years ago that upon my first residence in a subtropical country, the existence of typhoid was dogmatically denied, for malaria was then the dominant diagnosis. We now know that typhoid fever is favored by warm weather and that this disease has long prevailed as a serious problem in tropical and subtropical lands.

As a rule, most diseases that have a seasonal prevalence show that this is more than a fortuitous tendency; indeed, is a distinct part of the natural history of the disease. The peak of the curve of many seasonal diseases follows the latitude. Just as blossoms come out two or three weeks later in Boston than in Baltimore, so also the seasonal diseases are often several weeks later in Boston than in Baltimore. The effect of latitude is striking and significant. In the southern hemisphere, the season for plant life and the season for disease prevalence are alike reversed. Sometimes it is not so much the month of the year as the condition of the weather at the time which influences disease prevalence. Thus, rheumatic fever reaches its peak in March and April in the United States, but in September and October in England; both these seasons are the damp changeable times of the year.

Among the various uses of a study of seasonal prevalence is the light it throws upon the mode of transmission and other factors concerning disease, especially a disease about which our knowledge is unsatisfactory. Take infantile paralysis as an example. The prevailing opinion among public health administrators is to regard this disease as a contact infection spread by means of the discharges from the mouth and nose. Abortive and missed cases and also carriers are believed to play an important part in its spread. Infantile paralysis has a very distinct summer prevalence. Cold weather outbreaks are comparatively rare occurrences, and in this country represent almost invariably the tailings of a previous summer epidemic. The disease normally reaches its peak in August and September and usually declines sharply with the coming of cool weather. Furthermore, infantile paralysis has a predilection for rural distribution and other epidemiological factors which run counter to the epidemiology of diseases spread by contact.

A closer study of the seasonal prevalence of infantile paralysis shows that while the disease recurs with great regularity every summer, the curve is not a simple curve. A study of the seasonal prevalence of this disease by Dr. W. L. Aycock and Dr. Paul Eaton[2] in my laboratory has disclosed the fact that, preceding the summer peak, there is a minor rise which takes place in the spring. In other words, there is an increase in the number of cases about March and a subsidence in April and May before the definite rise which occurs in June up through July and August, to decline with the cool weather of September. Thus, the seasonal curve of infantile paralysis is bimodal. The significance of this is not clearly evident, but indicates that the disease is spread in more than one way, one factor being operative to cause the minor spring rise and other factors being responsible for the summer peak. A similar study of the curve of typhoid fever shows it also to be bimodal, thus lending countenance to the hypothesis that infantile paralysis may have several methods of spread.

Epidemics of pneumonic plague are restricted to northern climates and occur especially in cold weather. The Manchurian epidemic of 1910 occurred during the winter and was one of the most virulent epidemics of modern times, the case fatality rate being over 90 per cent. A limited outbreak, due to an infected squirrel, occurred in California in 1919. Bubonic plague occurs in the summertime and has an entirely different epidemiology. So far as seasonal prevalence is concerned, the pneumonic form of the disease follows the general rule of respiratory and contact infections, while the bubonic form runs true to form of the insect-borne diseases.

A number of diseases show two peaks, one in the spring and the other in the autumn. This is frequently the case not only with the acute respiratory and throat infections, but also with tuberculosis, nephritis and rheumatism, as well as neuroses, which may have a higher peak in the autumn than in the spring. The causes of biseasonal prevalence are not at all clear.

Seasonal prevalence is wrapped up with geographic distribution and is one of the underlying factors in the distribution of disease over the earth's surface, for the reason that seasonal prevalence naturally becomes a function of latitude. In general, diseases of the respiratory tract flourish in the colder regions, whereas in the warmer areas intestinal infections and parasitic fevers are apt to prevail.

Huntington's book on "Civilization and Climate" reawakened stimulating and suggestive studies upon the way in which climate

[2] *American Journal of Hygiene*, in press.

controls human progress through its direct influence on health. Civilization has shown its greatest advance in the temperate zone. In a second publication, "World Power and Evolution," Huntington analyzes the effect of temperature and humidity on the death rate by means of climographs. He states that the climate which is ideal for the stimulation of human progress is one in which the mean temperature does not fall below a mental optimum of 38° F. or rise above the physical optimum of 60–65° F. This ideal climate must have variability, from say 19° F. in the coldest month of the winter to 73° F. in the warmest month of the year. A uniform climate becomes monotonous; variability is stimulating and important. Huntington uses cyclonic storms as an index of variability, assuming twenty such storm centers a year as an optimum. Relative humidity is also important, the extremes of humidity and dryness being unfavorable. Within these limits moisture seems more favorable than dryness.

We know that the physical condition of the air about us has a greater influence upon our well-being than its chemical composition. A warm, still, humid day is enervating and causes a rise in our bodily temperature; this also is responsible for discomfort experienced in a close, crowded and poorly ventilated room. In addition to the physical condition of the air, there are other factors that make up the sum total of weather and climate, so far as their effect on man is concerned. We are just learning the importance of sunshine and finding out that it is especially the powerful rays of short wave length that influence health. That we are responsive to our environment is clear. There are seasonal changes in physiologic activity. Mental, physical and emotional status vary with the weather and in part perhaps are influenced by it. The causes of seasonal changes in health and disease are varied, complex and largely undetermined.

Grouping of Diseases in Accordance with Seasonal Prevalence

The communicable diseases divide themselves naturally into three groups so far as their seasonal prevalence is concerned: (1) the insect-borne diseases, (2) the intestinal infections and (3) the diseases of the respiratory tract.

The Insect-borne Diseases

The group of diseases which are insect-borne prevail almost entirely during the summertime, that is, during the hot, moist season of the year, which is also the season of maximal activity in the biology of the insect vector. The insect-borne diseases give us the

best examples we have in epidemiology of endemicity and also the clearest cut instances of seasonal prevalence. We have no record of an epidemic of yellow fever in the wintertime. It is not conceivable that yellow fever could prevail in any district in the absence of Stegomyia calopus. Strange to say, we have a few curious exceptions to prove the rule. Thus, typhus fever prevails in the winter season and subsides with warm weather. This paradox is explained by the fact that lice are more common in cold weather and temperate climes than in warm weather and the tropics. The influence of temperature is well shown by the fact that typhus fever prevails in Mexico City but is absent in Vera Cruz. There is evidently something in the bionomics of the louse and perhaps in the cycle of the rickettsia bodies that makes cold weather favorable and warm weather unfavorable for the completion of the circle of events necessary to complete the chain from man to louse and back to man.

Even winged insects, which ordinarily are most abundant in warm weather and have their maximal flight in the summertime, sometimes cause winter outbreaks. This, however, can happen only when artificial conditions are provided. Thus, Mackenzie[8] reported an outbreak of malaria in southeastern Russia during the winter of 1922–23. The disease affected up to 90 per cent. of the population in many areas. The epidemic spread steadily throughout the winter with the thermometer varying from 20° to 30° C. below zero from November until March. The spread of the disease during the extreme cold appeared to be due to the fact that the drinking-water butt, combined with the almost tropical heat of the log houses of the peasants, afforded ideal breeding places for anopheles remaining in the huts from the summer. During the intense cold of winter, both the larvae in the water butts and adult anopheles in dark corners could readily be found in a large proportion of the peasants' houses.

The Intestinal Diseases

The seasonal prevalence of the intestinal diseases has a general resemblance to that of the insect-borne infections. Both normally have a warm weather prevalence. This is the case with typhoid fever, cholera, dysentery and the summer complaints of infants. The incidence and intensity of gastro-intestinal infections become greater as we approach the tropics.

While the curve of the intestinal infections shows a marked similarity to that of the insect-borne group of diseases, the one may be distinguished from the other by the fact that winter-borne

[8] *Lancet*, 1923, 55, 1225.

outbreaks of insect-borne diseases are unusual, whereas winter-borne outbreaks of intestinal infections frequently occur. Thus, "normal" or residual typhoid fever shows a marked summer prevalence and recurs in endemic centers summer after summer like an annual crop—provided there is a clean water supply. On the other hand, water-borne typhoid fever has a predilection for the winter season, when the water is cold. The vast majority of water-borne outbreaks of typhoid fever that have been recorded have occurred in the late fall, deep winter or early spring—avoiding the warm months. It is quite possible to tell from a glance at the seasonal curve of typhoid fever extending over a period of years whether water-borne infection is playing a serious rôle. When cities like Albany, Philadelphia and Chicago improved their water supplies, the typhoid curve was changed in two particulars—the rate was markedly lower and the curve of seasonal prevalence was reversed.

The year before last I encountered in Russia an interesting example of seasonal prevalence. Typhus fever was epidemic throughout the winter, declining in the spring and practically disappearing with the coming of warm weather. As typhus fever left, cholera appeared and increased during the summer, in turn to make place for typhus when the cool days of autumn arrived. The interesting part about this cholera outbreak was that so far as my investigations disclosed, it was quite independent of water-borne infection; at least no drinking water supply was infected on anything like the scale of the Hamburg epidemic in 1892. The summer cholera in Russia was a communicable infection in which water played a minor rôle, and its seasonal prevalence ran true to form.

The seasonal prevalence of bacillary dysentery and the diarrheas of children is quite constant in all parts of the world and correlates with the warm, moist, enervating time of the year.

Now that the summer group of intestinal infections has been largely controlled, the wintertime has become the unhealthy season of the year—at least in temperate climes. The greater morbidity and mortality during the cold weather dominates the total death curve in a country like the United States.

The Respiratory Group

The diseases of the respiratory tract have their maximal prevalence during the cold and changeable seasons of the year. This group includes, first of all, the acute infections of the respiratory tract, such as common colds, sore throats, bronchitis, influenza and pneumonia. Next, there is a group of epidemic diseases, the viruses of which are spread by the discharges from the mouth and nose,

which likewise have a preference for cold weather. This group includes diphtheria, scarlet fever, whooping cough, mumps, measles, cerebrospinal fever, smallpox, etc. While most of these infections have a predilection for the cold weather, it must not be inferred that they can not occur in warm weather. As a matter of fact, they all smoulder in sporadic fashion during the off season, which is probably the way in which they are kept alive. Furthermore, in addition to this occasional or endemic occurrence, many of these communicable infections break out in the summertime as veritable epidemics. Thus, we have occasionally epidemic outbreaks of common colds, measles, smallpox, influenza, etc., in warm weather. The tendency is well illustrated in the periodicity of influenza. Following an epidemic, the succeeding waves recur at intervals of thirty-three weeks; but, if this point in the cycle is reached during the summertime, the periodic expectation is apt to be missed or slight. If we may trust the records of the epidemiology of influenza, there are accounts of sixteen epidemics having occurred in the summertime. Despite these occasional and unusual occurrences, the respiratory diseases are clearly favored by the conditions accompanying cold, changeable winter weather and are deterred by the warm summer season.

The respiratory group of diseases is the most prevalent and damaging to which flesh is heir, and while they prevail more especially in temperate, cold and variable climates, they occur also in warm latitudes and even in the tropics. They are endemic everywhere. Epidemics are frequent and pandemics sweep the world like a devastating plague about once a generation. As a group, the respiratory diseases are less well understood and hence less controllable than the intestinal infections.

Another point of special interest in connection with this group is that the usual mode of spread is by contact and through discharges from the mouth and nose. The respiratory diseases, however, may also be transferred in many other ways. Thus, infection may be contracted indirectly in food and drink, by hand-to-mouth infection or by fomites, such as cups, spoons and other things that are mouthed.

Deaths from tuberculosis, cancer, diabetes and other diseases show a tendency to seasonal prevalence, despite the fact that these diseases in themselves are little influenced by season. This is due to the seasonal influence of the important complications of such chronic and debilitating affections. Thus, deaths from diabetes show a curve corresponding to that of pneumonia and bronchitis. The complications dominate the picture.

Another interesting factor in the cold weather prevalence of common colds, influenza, bronchitis, sore throat, pneumonia, measles, scarlet fever, diphtheria and a long list of diseases spread by the discharges from the mouth and nose is that in all this group contact infection is the main mode of spread. The spread of disease by contact implies close personal association. Close association favoring the spread of contact infections under poorly ventilated and crowded conditions is a concomitant of cold weather. In winter there is a tendency to huddle together; in summer, to spread out. Crowding, then, is believed to be a factor which accentuates the tendency to the seasonal prevalence of the contact diseases. On the other hand, it can not be the dominating factor, for we sometimes see these very same diseases occurring as sharp outbursts in the summertime, in the tropics and even under rural conditions. Influenza spreads like wildfire in sparsely settled country districts. A contact epidemic may break out at any season and once started runs its course in spite of weather or climate. Epidemics of smallpox and measles occur in the summertime. Gorgas found pneumonia to an excessive degree in a warm country such as Panama. This was aggravated by overcrowding and a susceptible population.

Diphtheria shows a wide seasonal range. An outbreak may occur at any time of the year, but is much more likely to happen in the early winter than at any other time. Diphtheria is a disease of cities and of colder latitudes. It is rare in the tropics and subtropics, even in large cities. In other words, the prevalence of diphtheria depends upon two factors, climate and concentration of population. The death-rate in northern states and cities is generally higher than in the southern. Scarlet fever is more variable in its occurrence than diphtheria. High points may be reached at any time from the autumn to the spring: the diśease is rare in summer. Measles shows wide seasonal variation. The peak of the curve usually occurs in the cold weather, but may be reached in the summer months of June, July or August.

One of the most interesting facts concerning seasonal influence on disease is the agreement to be noted in cities widely separated and of diverse climates. Much more could be learned by comparisons of this sort.

Hence, neither the condensed, crowded, gel state of humanity in the winter, nor the sol state of dispersion in the summer is an adequate explanation of the seasonal prevalence of the respiratory group of diseases.

A Discussion of the Causes of Seasonal Prevalence

The causes of seasonal variation in the prevalence of disease are varied and complex and not well understood, but they are enticing

fields for study. Some of the probable causes, such as the direct effects of weather and climate, the features of crowding and the problems of susceptibility and immunity, have already been touched upon. These and others lend themselves to discussion.

There may be a lowered resistance, which expresses itself as an increased susceptibility at certain seasons of the year. On the other hand, there may be an acquired immunity of part of the population which acts as baffles against the spread of infection. There may be heightened virulence on the part of the parasite, or if not increased virulence, at least heightened activity, so that its powers of penetration, invasion and primary attack are facilitated at certain seasons and handicapped at others.

The susceptibility of the population helps us in part to explain periodicity but throws little light upon seasonal prevalence. Thus, a severe epidemic of smallpox, plague or typhus fever will leave meager susceptible material for another outbreak. Yellow fever in an endemic area is kept alive by non-immune immigration and new births. It is the fresh susceptible material that feeds the flame. The disease will die out in a city with no influx of strangers, the new-born being insufficient to keep the fire burning. On the other hand, the two-year periodicity of measles is accounted for by the susceptible crop of new babies. This explanation, however, does not satisfy Brownlee, who regards the well-known cyclic recurrence of this disease as due to some factor in the life history of the parasite still unknown. It has been observed that measles shows little tendency to spread during the odd year, despite the presence of susceptible material. Susceptible population in itself is not a satisfactory explanation of the recurrence of disease at definite seasons of the year, although it is evident that seasonal prevalence depends upon susceptible material.

The amount of disease in the community depends to a certain extent upon the amount of virus as well as the facilities for its transfer and related influences. The amount and distribution of the active principle is probably one of the prime underlying factors in the generation of some diseases in epidemic proportions. With some crops, the amount of the harvest depends primarily upon the quantity of seed and its distribution. Studies in experimental epidemiology by Webster indicate the importance of this factor in epidemics of mouse typhoid. Other diseases, such as smallpox and measles, probably propagate themselves entirely independent of the amount of the virus. This is not the case, however, with streptococcic sore throat, which is believed by Bloomfield and Felty to correlate with the amount of the virus and facilities for transfer by close and prolonged contact during cold weather. Dudley has dis-

cussed this matter from a clinical standpoint and brought out the principle which he refers to as "the velocity of infection."

Dosage, or the number of bacteria, also is an important element in determining disease as well as the amount and distribution of the causal agent in the community. It takes at least ten virulent tubercle bacilli of a certain strain to infect a guinea pig. It requires many more tubercle bacilli by the mouth than by the lungs to induce tuberculosis. On the other hand, strains of plague and pneumonia may be so virulent that one bacterium is enough to start a fatal infection. Dosage varies with different infections and with the same infection under different circumstances.

Webster[4] reminds us that the equilibrium of an infectious disease in a given community is determined essentially by three factors: (1) microbic distribution, (2) microbic virulence and (3) host susceptibility. To avert or modify an epidemic, one of these factors must become changed. Webster's studies on mouse typhoid plainly indicate that the inherent virulence of each strain of this bacillus remains constant. He therefore regards virulence as a relatively fixed quality. Racial immunity is acquired slowly if at all. Consequently, the control of epidemics of mouse typhoid depends on influencing microbic distribution. Streptococcal infections in man, such as hemolytic sore throat, scarlet fever and erysipelas, are milder and probably less frequent than formerly. It is quite likely that these infections are becoming less prevalent than formerly. It is quite likely that these infections are becoming less prevalent and less severe because of the measures taken among hygienic people to prevent the distribution of large numbers of virulent streptococci broadcast among the people. In other words, the population now is probably much less heavily seeded with virulent streptococci than it was before the days of isolation, disinfection and understanding.

The seeding of communities with a virus is therefore an important element in epidemic and endemic prevalence. Cerebrospinal fever occurs usually in cold and changeable weather. Carriers are common in the wintertime, rare in summer. The carrier state is persistent in cold weather but recedes spontaneously on the coming of warm weather. Camps in warm climates for carriers of meningococci were advocated during the World War.

Common colds increase the number of pneumococci in the mouth. Normally, about 50 per cent. of the healthy population are carriers of pneumococci. This percentage jumps materially in persons who have common colds. Pneumococci, as well as Pfeiffer's

[4] *Am. Jour. of Hyg.*, 4, 34, 1924.

bacillus and other mouth organisms, increase during attacks of influenza, whooping cough and measles. Scarlet fever seems to cause an increase in the number of diphtheria bacilli in the throat, and a somewhat similar symbiosis is found in the epidemiological relation between other infections.

In a well-seeded community in which an equilibrium has been reached between host and parasite, the introduction of susceptible persons will cause an epidemic occurrence not only among the newcomers but also among the old residents. This can be explained by the fact that the new and susceptible are attacked, and this increased number of new cases causes a general increase in the amount and dispersion of the infection. In other words, the equilibrium reached between the host and the parasite in endemic regions can readily be disturbed so that an epidemic outbreak results. The changes in the body due to season may likewise disturb an equilibrium sufficiently to account for the seasonal tendencies of some infections.

What effect carriers may have upon seasonal fluctuations of disease is not at all clear. The carrier state itself shows seasonal variation in several instances. The best example is found in meningococcus carriers, which are comparatively frequent in cold weather and relatively scarce in warm weather. In diphtheria, the carrier state has been studied both as to season and as to virulence. The number of virulent carriers is directly proportionate to the number of cases and the seasonal curves of the two therefore largely correspond. It is rare to find a virulent diphtheria bacillus in a normal throat or nose, except in persons who have had direct and recent contact with a case of the disease. Carriers explain the vagaries of endemic cases; they account for water-borne outbreaks of typhoid fever and milk-borne epidemics of scarlet fever. Carriers are the storehouse of infection between epidemics, but they do not explain the seasonal prevalence of disease.

The question of virulence and its relation to season is still an unsolved problem. Some infections, like typhoid fever, have quite constant case fatality rates in all seasons, in all places and in both endemic and epidemic situations. With typhoid fever, then, it is possible to construct a satisfactory curve of incidence from the mortality records. This is not so with most other diseases.

The relation of virulence to disease is fundamental and the solution of the problem will require accurate data before a statement can be made with any assurance of finality. Furthermore, this question must be settled for each disease separately, for each disease is a law unto itself. A number of diseases show marked changes in severity at different times and under different circumstances. I have been through some yellow fever epidemics with a

case fatality rate of 37 per cent., and through others a few years later in which the rate was less than 5 per cent. I have also seen the same great variation with smallpox. Scarlet fever is now much milder on the average than formerly. Records of epidemics of infantile paralysis show a great variation in virulence—from 5 to 30.7 per cent. case fatality rate. Flexner and Amoss have shown that strains of the virus passed through monkeys under laboratory conditions fluctuate in virulence from time to time.

We do not know whether disease is more or less fatal on the up or the down curve of an epidemic. There is evidence to show that as an epidemic dies out, the disease becomes more severe, and this has been explained by the fact that as the disease is on the run, the very susceptible are chiefly attacked. Probably the best studies with complete data on this score are those of the great epidemic of infantile paralysis in New York in 1916. This was the most extensive epidemic of this disease in the history of the world—29,000 cases and 6,000 deaths. The case fatality rate was 27 per cent. throughout the rise, peak and fall of the curve. Dr. W. L. Aycock and Dr. Paul Eaton[5] made a study of 38 different epidemics occurring in various parts of the world between 1894 and 1921, comprising 20,568 cases, in which the maximum case fatality was 30.7 per cent., the minimum 5 per cent. and the average of all 20.8 per cent.

Even in a well-organized community where public health administration has reached a high level of excellence, the reporting of deaths and especially of cases is imperfect and incomplete. There are many sources of error. There are fashions in diagnosis which have their vogue and pass. Furthermore, there is a psychology which influences diagnosis and the reporting of disease. Thus, a newspaper scare will at once cause a jump in the number of reported cases and deaths, especially in the group of ill-defined diseases. This is notably the case with influenza. Often typhoid fever and infantile paralysis rise with the intensity with which attention is directed to these diseases, and fall when they pass out of mind. In a study made by Dr. Aycock and Dr. Eaton in my laboratory,[5] it was found that in infantile paralysis the case fatality rate is much higher in cold weather than during the summer season. This would indicate that the disease is much more severe during its sporadic occurrence in the off season than during its summer prevalence. A deeper study of this phenomenon, however, throws serious doubt upon this inference, for experience indicates that infantile paralysis has about the same case fatality rate the year round. It is probable that during the off season only the occasional severe and fatal cases are recognized and reported, while a larger propor-

[5] *Am. Jour. of Hygiene*, in press.

tion of those of the mild and ordinary type occurring in this season are missed than during the months when the disease is conspicuously in mind.

Generalizations concerning seasonal prevalence are hazardous, for each particular infection has its own vagaries. Each disease must be studied in and out of season. Its prevalence may then be correlated with other factors in order to get a true epidemiological picture.

The parasite has its own problems and struggle for existence. If it becomes too malignant and destroys the host before it can get out, it defeats its own purpose. The adjustment towards an equilibrium is therefore complex and exceedingly intricate.

Many diseases follow the temperature curve so closely that there seems to be a direct causal relation between temperature and seasonal prevalence. When the matter is studied a little more intimately, temperature as a direct cause is not so evident. We have the testimony of Arctic explorers that there is little pneumonia among the natives and among those visiting polar regions. It seems also to be a matter of observation that when Esquimos and Laplanders come to our climate, they are especially liable to the pneumonias, and the fatality among them is great. We have the statement of the Grenfell expedition that influenza when carried to the countries of Greenland caused havoc with a very high mortality among the natives. Other reports coincide with this experience. Epidemics of pneumonia and influenza are not confined to cold or even temperate zones, but are seen quite frequently in the tropics. Pneumonia is one of the chief causes of death among the laborers on the fruit plantations in Central America. According to Vaughan, studies in Michigan show that the lower the temperature, the greater the number of cases of pneumonia in that state. The warm cities in the United States have less pneumonia than cold cities, but the warmest city does not have the lowest rate, nor does the coldest city have the highest rate. Temperature alone, therefore, is not the deciding factor.

Scarlet fever shows a distinct relation to temperature. The disease is usually high in the colder cities and almost absent in Atlanta, Los Angeles and New Orleans; it does not even appear in the annual report of the chief health officer of the Panama Canal Zone. Diphtheria differs materially from scarlet fever in that it is prevalent in warm as well as in cold regions. Measles, while showing a very distinct preference for cold weather, prevails in both cold and warm countries.

According to Huntington, the death-rate increases as the temperature departs in either direction, hot or cold, from the optimum,

which is around 64° F. Furthermore, whatever this death-rate, moisture lowers it. At 64° F., humidity has the least influence. This is indicated for the total death-rate, for deaths from non-communicable diseases and from pneumonia, as worked out by Greenberg for certain eastern cities and by Vaughan for Detroit.

Temperature is only an index of the many complex factors that make up the sum total of season and climate. Heat is depressing, cold is stimulating. The ill effects of bad air and the good effects of fresh air are due primarily to the physical condition of the air which influences our heat-regulating apparatus. We manufacture more heat than needed and therefore we must lose heat in order to prevent heat stagnation. The loss of heat depends largely upon temperature, humidity and the motion of the air about us. When, however, we consider seasonal changes, we bring in other factors, such as sunshine, storm and variation.

Seasonal influence can not be ruled out, as Huntington states. In other words, the highest death-rate in the spring may not correlate with dryness, but with the fact that people are more fatigued by the strain of winter and are as a rule less resistant to pulmonary infections. One of the causes of seasonal prevalence may be due to the stress of increased heat production and metabolism. The body becomes weakened as the winter season goes on and pneumonia continues to increase until the advent of warm weather in the spring. The peak of the disease is reached at different months during the winter in the northern United States, but in any case, there is always more of the disease in February than in August. In other words, temperature seems to exercise a greater influence so far as pneumonia is concerned than moisture.

Vaughan offers the interesting speculation that it is not so much the cold or cold weather that affects us as our semi-civilized response to this cold. Outdoor cold drives us to live in overheated atmospheres indoors. We spend our winter days in temperatures between 70° and 80° F. Houses are overheated, factories are overheated and offices and stores are overheated. It is this fact which helps explain the apparent contraindications in the effect of weather on pneumonia. Physiologically, cold is stimulating and heat is depressing. Practically, cold weather places a greater strain on the body in metabolism and in waste elimination. The body is more exacting. Working under a heavier schedule, it must not be denied its rest. If given a chance—ample sleep, living in cool rooms—the body responds to the stimulation of winter.

It is said that tuberculosis patients do much better in the cold season. Sick people so care for themselves as to counteract the unfavorable concomitants of cold. By so doing, they are in a position

to reap in full the benefits of cold. Arctic explorers are not prone to pneumonia. Thus, it is the habits of life which cold weather induces, rather than the weather itself, which leads to this disease. It is for this reason that we may regard much of the pneumonia as humanly preventable. Studies have shown that it increases as physical vitality decreases. When this fact is fully sensed, Vaughan believes that we will adopt the habit of easing up in February and resting in order to counteract fatigue. A more thorough knowledge of the weather combinations will place us on guard in the future, and when the relation between weather and disease is better understood, we may be able to predict the health outlook and even prepare in advance for eventualities.

It is assumed that the limitations imposed by weather and diet cause many persons to lead unhygienic lives in winter. For some of these, spring brings a welcomed tonic change; others seek it by removing to a different locality. Taking a spring tonic may have been an old-fashioned notion, but it was moreover an expression of the influence of winter conditions.

A change of climate brings more than a change of scene, and its effects are often real. A change of climate may bring rest and recreation, and also brings the influence of latitude, diet, temperature, moisture and sunshine; it not only means favorable weather conditions, but also removal from smoke, dust and other noxious influences in the air, water and food of the environment in which the person lives. Even the psychologic influences that come with such changes often account for the benefits. When it is all summed up, we must admit that the favorable effects of a change of climate may be due to causes that are not understood at present.

The value of sunshine has always been appreciated, but we have only understood its importance since the work on heliotherapy in tuberculosis, and more particularly the comparatively recent observations upon the health-giving virtues of the direct rays of the sun in preventing and curing rickets.

It is extraordinary that the utilization of certain foodstuffs depends upon sunshine. The rays of short wave length in sunshine have great power to influence the chemical and physical processes of life. Certain substances in buckwheat, also hematoporphyrin or eosin, are not harmful if the animal is kept in the dark, but exposure to sunshine causes serious and even fatal injury. The photodynamic activity of sunlight must greatly influence our well-being both in and out of season. Esquimo children escape rickets because they eat the livers of fish. The negro child in New York is apt to develop rickets unless given cod liver oil.

It has recently been shown that even the weight of certain organs in the body varies with season and directly with the amount of sunlight. Sunlight, then, is one of the potent influences that make up the sum total of climate and explains the seasonal variation in some diseases.

Climatology, from the human standpoint, has not yet reached the dignity of an exact science. It still banks on combinations of tradition, unverified beliefs and empiric deductions.

A natural explanation of the winter prevalence of contact infection is the condition of crowding in cold weather and the tendency to dispersion in warm weather. Diseases spread by discharges from the mouth and nose are favored by close personal association. People who live together, eat, sleep, work and play together, furnish multiple opportunities for the transmission of infections of the class in question. During the war we found that messmates would run as high as 60 and even 80 per cent. of carriers of meningococci. Bloomfield studied the seasonal prevalence and epidemiology of septic sore throat among the nurses of the Johns Hopkins Hospital, and found that intimate and prolonged association was a factor in the transmission during the wintertime of sore throat due to a hemolytic streptococcus. Gorgas found crowding to be one of the factors in the excessive prevalence of pneumonia among the miners on the Rand in South Africa. It is unnecessary to multiply instances. The effect of crowding is well known, yet it does not give a satisfactory answer to seasonal prevalence.

The schools have also been implicated in the increased prevalence of certain diseases in the fall and winter. Students of the subject, however, are satisfied that the schools have comparatively little effect upon the seasonal curve of cold weather infections. Vaughan states that the seasonal curve of disease implicates the weather more than the school. Lobar pneumonia certainly can not be influenced by school attendance. In spite of the opening of school, the peak of scarlet fever is not reached until January, and a secondary high mark occurs in April. Measles is even more deliberate and fails to reach its maximum until May. Vaughan believes that there is nothing in the behavior of these diseases which involves the school as a breeder of disease and states that it is the weather influence in the long run which controls the form of the curve.

In man, as well as in the lower animals, there are distinct seasonal changes which at first sight seem to have nothing to do with disease. The best known of these is hibernation. There is also a seasonal period for reproductive activity. Many animals show variation in the growth of hair, feathers and antlers at different

seasons of the year. These and other periodic physiological activities may be underlying factors in the seasonal prevalence of some diseases. Seasonal changes in metabolism in the lower animals are well recognized.

Beckmann,[6] in a consideration of the effect of season on disease, attributes the absence of such marked seasonal alterations in man to the fact that with higher development comes a better regulating mechanism against extraneous influences. But even in man there are distinct alterations in metabolic activity at different times of the year. Thus, measurements have shown that in spring the hair grows more rapidly than at other times; body activity as a whole is lessened in winter, so that the usual amount of time spent in sleep is much increased over the summer sleep among people not too artificially regulated by customs and alarm clocks. Presumably, this is related to hibernation in other species. It is said that pulse rate, temperature and respiration are highest in winter, and recently it has been found that the height of the capacity of the blood to bind carbon dioxid is reached with the shortest days of the year. In the spring there is a distinct fall in the carbon dioxid tension of the blood, which implies a decrease in the alkali reserve.[7] Although these variations are exceedingly small, they gain in the possibility of significance through the fact that they appear at the time of year when most diseases of seasonal variability are making themselves manifest, excluding diseases dependent on such obvious seasonal matters as insect transmission and food supply.

Man's heat-regulating apparatus is better than that of many of the lower animals. Nevertheless, it is responsive to external temperatures. Thus, a stay for three hours at 40.4° C., with a relative humidity of 95 per cent., will cause a rise of several degrees in the temperature of the body. Likewise, a lowering of body temperature soon results when either the whole or part of the body is exposed to cold air or immersed in cold water. The classic experiments of Pasteur with chickens which are rendered susceptible to anthrax if their feet are kept in cold water is pertinent in this connection.

An illuminating instance of the effect of climate upon physiological activity is found in the laborious observations made by the pioneer American physiologist, William Beaumont, on the gastric conditions in his classic patient, Alexis St. Martin. He recorded with great care the meteorological details and from one group of experiments concluded that "the variations of the atmosphere produce effects on the temperature of the stomach, a dry atmosphere increasing and a humid one diminishing it."

[6] *Deutsch. med. Wchnschr.*, 1922, 48, 1409.
[7] *J. A. M. A.*, 1923, 80, 476.

Seasonal prevalence is also associated with endocrine imbalance. Hibernation is known to depend upon the activity of certain ductless glands. The way this may affect disease directly and indirectly is evident. Moro found that the incidence of infantile tetany increases in January and February, rises to a peak in March and falls nearly to zero in the summer. The galvanic irritability follows a similar curve and in guinea pigs a seasonal variation has been found in respect to their sensitiveness to caffein. Even mental instability has a seasonal tide, for the curve of suicide shows a definite peak in the spring. Other mental disturbances follow a similar curve, with a second rise in the autumn in some types.

Hyperchlorhydria is said to show a distinct rise in the spring and autumn, which may possibly be correlated with the diet. Hyperthyroidism seems to show a double curve. Rusznyak[8] believes that the change from winter to summer or from summer to winter arouses an adaptive mechanism, the activity of which produces a condition of instability during these transition periods, and hence pathologic conditions become more conspicuous until seasonal adjustment is completed.

A very interesting contribution to this subject by Brown, Pearce and Van Allen[9] has just appeared. They studied seasonal changes in organ weights and their relation to meteorological conditions. It is well known that many of the endocrine glands of normal animals undergo rhythmic changes in weight per unit of body weight, which conform in general with seasonal conditions. The authors named found that in the case of organs such as the heart, the kidneys and the liver, the transition from one condition to another occurred relatively slowly, and the maximum variation in any direction was distinctly less than that noted in the case of a number of the endocrine glands and the lymphoid tissues. The heart and kidneys showed a variation in weight amounting to approximately 20 per cent., while that of the liver reached upwards of 40 per cent.

On attempting to correlate this series of seasonal variations in organ weight with meteorological conditions, it was found that the majority of them corresponded in time and direction with prevailing conditions of sunlight. In general, the periods of maximum weights coincided with the high levels of daily sunlight, while the periods of minimum weight coincided with the low levels of daily sunlight. Furthermore, the change in direction and the transition from that condition to the other corresponded with the change in sunlight from winter to summer, or from summer to winter. What

[8] *Wien. Arch. f. inn. Med.*, 1922, 3, 379.

[9] *Proc. Soc. Exp. Biol. & Med.*, 1924, 21, 373.

is more significant, however, is the fact that the actual time and progress of the change followed the curve of the actual hours of sunshine rather than the theoretical curve or the uniform progression of the seasons. This was more noticeable in the case of some organs than of others. In fact, it appeared that the weight curves of some organs conformed more closely to the curve of temperature or to humidity than to the curve of sunshine, and that the degree of correlation in any case was subject to the influence of other factors. In other words, there are actual changes in the size and weight of organs which pursue a rhythmic course in harmony with the progression of the seasons.

The study of epizootics under laboratory conditions very closely imitating natural conditions is a new angle of approach and should throw light on the causes of seasonal prevalence. Topley in England and Flexner and his associates[10] in this country have studied mouse typhoid produced experimentally in laboratory animals. Experimental epidemiology with different types of infection carried out over long periods of time and under controlled conditions offers opportunity to unravel some of the mysteries of epidemic disease and its seasonal prevalence.

Hunt was the first to show the influence of diet as well as of season in the susceptibility to certain poisons. He demonstrated that mice are much more susceptible to a poison (acetonitril) in the spring following the winter diet than at other seasons of the year. The familiar spring outbreaks of pellagra follow the limited and one-sided diet of the winter. The eruptions of pellagra on the exposed surface of the body resemble sunburn and may be activated by the rays of short wave length. The seasonal prevalence of rickets in the spring is explained by the long-continued absence of sunshine during the wintertime. Scurvy is naturally influenced by season, depending upon the vitamin-bearing food, which is accessory. Stall-fed cattle in the wintertime secrete a milk containing little or no antiscorbutic vitamin, whereas milk from pasture-fed cows contains this important property. The seasonal character of certain cutaneous disorders is explainable on the basis of sunlight, while in others dietary variations are probably responsible. In some instances, as in teakwood poisoning, the lesions do not appear until after the activating effect of sunlight.

We see, therefore, that the seasonal prevalence of disease may have a number of different explanations. In some cases it is dominated by temperature, in others by combinations of temperature, humidity, air movements and other factors that make up the sum

[10] *Proc. Nat. Acad. Sc.*, 1921, 7, 319; *Jour. Exp. Med.*, 1922, 36. 9.

total of weather and climate. In some instances it is due to diet, in others to changes in susceptibility and resistance, as a result of seasonal factors. Virulence probably plays a rôle. Sunshine is an important factor in a group of maladies. Again, there is the normal seasonal fluctuation in the physiological mechanism of plants and animals, which is probably a response to the seasonal changes in our environment.

The comparison of epidemics with forest fires is a useful analogy and gives rise to such expressions as "the epidemic burned itself out," or "the epidemic smouldered," etc. These are figurative expressions and do not explain the course of the communicable infections; in fact, epidemics are living things.

The epidemic diseases are phenomena obeying the laws of life and we would expect them to have seasonal fluctuations, just as we commonly observe the influence of season in the plant kingdom. We know that temperature, moisture and sunshine are dominating factors in determining the appearance of blossoms and the activity of corn and thistles, and while each plant seasonally returns with great regularity, the amount of the crop correlates very definitely with a multiplicity of factors, such as the number of seed, the food in the ground, moisture, temperature, sunshine, etc. The amount of the crop, however, is not always determined by the coincident factors of weather, but may be a summation effect, the results of two, three, four and even five preceding seasons which will determine whether we are to have a good crop or a great epidemic.

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THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

ADDRESS OF THE PRESIDENT OF THE UNITED STATES[1]

The national government has a special and a profound interest in the gathering of the country's scientific leaders which you are beginning to-day in the capital city. No other single agency has so extensively relied upon the men and women of science as has the government. The personnel of the government service and the figures of the annual appropriation alike testify to this. The government has been foremost in employing, and most liberal in endowing science.

Let me say at once, however, that I do not intend to imply that we have been impressively liberal in dealing with the individual scientists who conduct these activities of the government. The most casual inspection of the salary lists of scientific workers in Washington will make very plain that it is toward science, not the scientist, that the country has been officially generous.

I was impressed with a new realization of the extent and importance of the scientific activities which center here in Washington by some figures showing the geographical distribution of members of your association. In proportion to its population there are more than five times as many of your members here as there are in any state.

I wish time would permit a brief suggestion of the amazing variety, the wide ramifications and the enormous value to the whole people of these scientific activities which are conducted under the administrative departments. Whether in studying the stars or in mapping the bottom of the sea; whether in making two blades of grass grow where one formerly grew; whether in developing a chemical compound that will destroy life or one that will save it; whether in weighing an atom or analyzing the composition of the most distant star—whatever the problem of human concern or social advancement, the scientific establishment of the government has enlisted the men and the means to consider it and ultimately to solve it.

So, as one particularly interested in this governmental university of practical and applied science, I welcome your great gathering to Washington. You represent the interests, the forces and the endless activities which literally from day to day are conquering new domains and adding them to the imperial realm of human knowledge. The future of civilization is well nigh in your hands. You are the wonder workers of all the ages. The marvels of discovery and progress have become commonplaces, simply because their number has paralyzed the capacity of the mind for wonderment. Those of us who represent social organization and political institutions look upon you with a feeling that includes much of awe and something of fear, as we ask ourselves to what revolution you will next require us to adapt our scheme of human relations.

[1] Given at the White House to members of the American Association for the Advancement of Science and affiliated societies meeting in Washington.

PRESIDENT COOLIDGE

Addressing members of the American Association for the Advancement of Science at the White House on December 31. The Washington meeting was larger than any previous meeting and probably the largest assemblage of scientific men that has been brought together in any country.

But we know that you are animated by a profound purpose to better the estate of men. We are confident that society will somehow devise institutions capable of adaptation to the changed circumstances with which you are surrounding the business of living in our world. We trust ourselves to you perhaps with some doubt as to what you may finally do with us and to us, but at least with firm convictions that your activities will save life from becoming very monotonous. And, besides, we realize that if we did not give you our confidence you would go ahead without it.

It is a wonderful thing to live in a time when the search for truth is the foremost interest of the race. It has taken endless ages to create in men the courage that will accept the truth simply because it is the truth. Ours is a generation of pioneers in this new faith. Not many of us are endowed with the kind of mental equipment that can employ the scientific method in seeking for the truth. But we have advanced so far that we do not fear the results of that process. We ask no recantations from honesty and candor. We know that we need truth; and we turn to you men of science and of faith, eager to give you all encouragement in your quest for it.

SOME ASPECTS OF INTERNATIONAL COOPERATION[1]

We should think in terms of the cooperation of peoples and not simply of governments. Science knows no political boundaries; she recruits her conquering chieftains from all climes and races. It may be an Austrian monk, revealing the secrets of plant inheritance; or a New Hampshire farmer's boy who learns to fashion instruments of the utmost delicacy and precision; or a Serbian herdsman taking youthful lessons in communication by listening through the ground; or a Japanese devotee of medical research isolating and cultivating microorganisms. In this field all are coworkers and pride is not of race or of tradition, but of achievement in the interest of humanity.

You have properly and insistently urged that international cooperation in scientific research is not only desirable, but absolutely necessary. There are most important enterprises which, if undertaken at all, must be conducted by international collaboration. Take, for example, the world-wide study of earthquakes and of various astronomical phenomena. In history, archeology, zoology, botany, geology and in any other of what are called the natural history or historical sciences little progress can be made in the study of what is fundamental unless there is opportunity to examine all the parts and aspects of the earth. Thus it is manifest, as has well been said, that considered as a local science geology gave only fragments of the earth's history, these partial records being separated in such a way as to suggest intervening periods of cataclysm or destruction. This was the natural interpretation of early investigators, but to-day with a knowledge of a large part of the earth's surface these gaps have been filled and a continuous history is available. It is not possible to have a complete history of life if you have an interrupted geological record, and yet this history is the world's most important story and the foundation of philosophy. You can not have an adequate history of peoples, or even of governments,

[1] From the address of The Honorable Charles E. Hughes, Secretary of State, at the opening meeting of the American Association for the Advancement of Science at the Memorial Continental Hall, Washington, on the evening of Monday, December 29, 1924.

MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AT THE WHITE HOUSE

After a reception given by President Coolidge. On his right is Dr. J. McKeen Cattell, president of the association, on his left Dr. William Mather Lewis, president of the George Washington University and chairman of the Local Committee for the Washington meeting.

if you rely exclusively upon data which are obtained in any one nation. And when we come to the enlargement of our knowledge of the universe, whatever may be the value of the discoveries and interpretations made in any one observatory, it is obvious that there can be little progress unless there are stations widely scattered over the earth and the bits of knowledge thus acquired are pieced together.

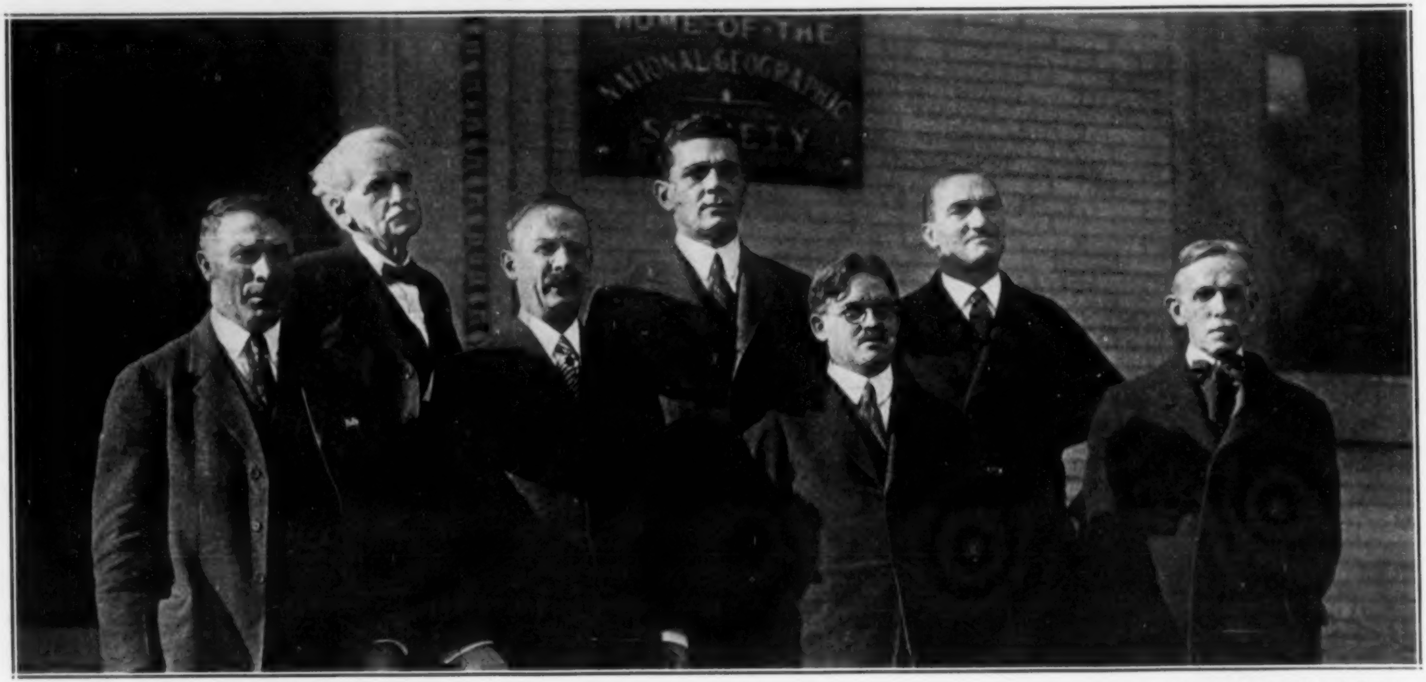
In truth, scientific achievement is not individualistic, but is the work of groups either consciously formed or produced by the essential correlation of effort. This essential cooperation has recently been described to me in this picturesque manner: "It grows like a building. One man may lay the capstone and get the credit, say an American scientist, but the stone may be laid upon a brick put into place by a Japanese and another by a German, and all may be held in place by the generalization of a Frenchman or a Scandinavian. A scientific problem is like a crossword puzzle worked out in a family circle. The solution may be held up until someone, perhaps accidentally, supplies the keyword that interlocks the rest." It may be added that in science we have a puzzle that is never solved; rather, a succession of puzzles, each answer raising new questions for which there must be a fresh collaboration.

It must be recognized that effective international cooperation depends quite as much on national organization and on appropriate interchanges as upon the creation of distinctive international bodies. There are national obligations which must be met and which can be made adequately only by the aid of governments.

The place of scientific research in our governmental economy should have more appropriate recognition. We develop bureaus, but with all our indebtedness to investigation we are still lacking in proper appreciation of scientific work. It is not comforting to our pride to think of the eminent scientists who are serving our government without adequate recompense or the losses in personnel we sustain by lack of appropriate provision for those who would be our greatest benefactors. If the test of civilization is in the sense of values there is little room as yet for boasting. The most competent organization of national scientific work which will seek, hold and suitably reward investigators of the highest rank is the fundamental requirement.

Then there is the responsibility which each nation should assume of properly assembling, arranging and safeguarding all data and records within the limits of its territory. Each nation should consider itself a trustee in the interest of humanity of all the results of researches in matters either touching itself directly or related to general questions dealing with wider regions. This safeguarding of data and records should be supplemented by coordination of effort and an assembling of results which will make it possible readily to command whatever may be found in any department as to any subject. The tendency is strong among departments to treat themselves as little separate governments, but, whatever distribution of endeavor may be necessary for convenience or economy, government in its relation to its guardianship of scientific data should recognize its undivided responsibility.

Each nation should also acknowledge its obligation in the interest of necessary international cooperation to make readily available to other nations its assembled data and records. The mutual understanding and support of all peoples relating to any subject of research will give ultimately to each investigation and to each separate locality the largest pos-



EXPLORERS IN WASHINGTON FOR THE MEETING OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS

In the group are, back row (left to right): Willis T. Lee, explorer of America's caverns, at Carlsbad, New Mexico; Frederick Wulsin, just back from a study of non-Chinese tribes of Kweichow, China, where he found fair-haired, blue-eyed Chinese, and Neil M. Judd, who spoke of his recent work at Chaco Canyon, where apartment dwellers are said to have held a tenant's strike 1500 years before Columbus discovered America. In the front row (left to right): Captain Robert A. Bartlett, Peary's companion on his dash to the North Pole; Dr. Gilbert Grosvenor, President of the National Geographic Society; Dr. Robert F. Griggs, leader of the expedition to the "Valley of Ten Thousand Smokes," in Alaska, and N. H. Darton, who just returned from exploring the ruins at Cuicuilco, New Mexico.

sible measure of result. This sense of mutual interest and obligation will be of especial importance in opening opportunities throughout the world for archeological inquiries. We deprecate all suggestions of the monopolizing of such researches or their results to the prejudice of reasonable requests to prosecute investigations on fair terms. We trust that our scholars and the representatives of our museums and scientific institutions will receive a cordial welcome wherever they go throughout the world, in the realization that they are not serving selfish interests but seeking to advance the knowledge of mankind. . . .

We should make acknowledgement to you for the benefit of the by-products of your labors. If to an increasing degree we have the security of sound public opinion, if the extravagances and diatribes of political appeals fail of their object, and if, notwithstanding the apparent confusion and welter of our life, we are able to find a steadiness of purpose and a quiet dominating intelligence, it is largely because of the multitude of our people who have been trained to a considerable extent in scientific method, who look for facts, who have cultivated the habit of inquiry and in a thousand callings face the tests of definite investigations. With scientific applications on every hand, the American people are daily winning their escape from the danger of being fooled. There are, it is true, many false prophets who are active in those areas of exertion where patient inquiry and regard for facts are not prized, but their following, while strident, is apparently not increasing.

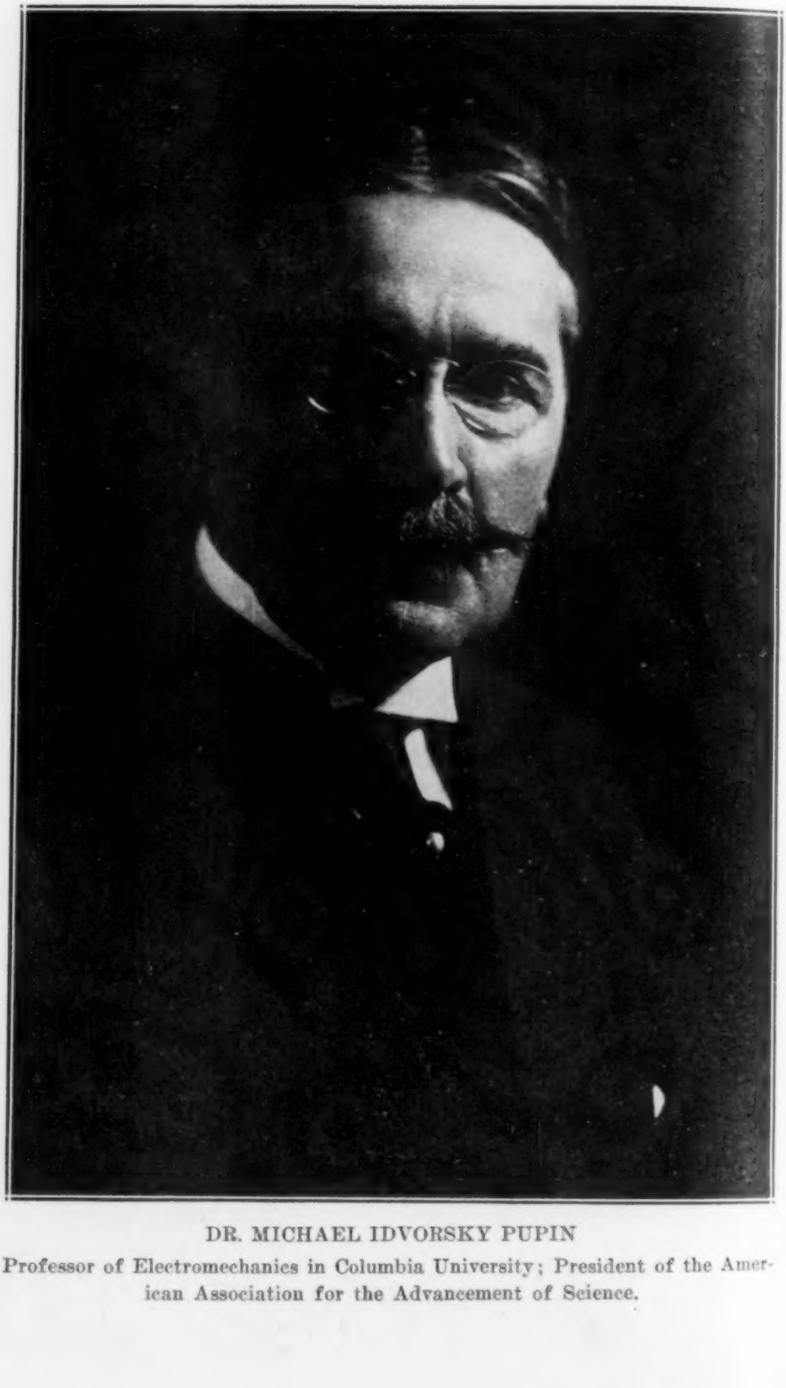
We need your method in government; we need it in law-making and in law-administering. We need your interest in knowledge for its own sake; the self-sacrificing ardor of your leaders; your ceaseless search for truth; your distrust of phrases and catchwords; your rejection of every plausible counterfeit; your willingness to discard every disproved theory however honored by tradition, while you jealously conserve every gain of the past against madcap assault; your quiet temper, and, above all, your faith in humanity and your zeal to promote the social welfare. We need your horizon; your outlook on the world. We need the international cooperation which makes more effective the essential national endeavor and brings us nearer together as members of one human family, who in the presence of science can not remain estranged, but must find means of reconciling their several interests in the harmony of their common aspirations and for the common good.

SCIENCE AND SERVICE[1]

A LARGE percentage of our good agricultural soils have been appropriated, and the further expansion of crop production to feed our growing population must come largely through utilization of the poorer land or through more intensive cultivation and fertilization of existing farms. Even more is this true of our pasture and range lands, the *per capita* area of which has been reduced by almost one half since 1890.

Using almost as much timber as all the rest of the world combined, the United States passed the highest point of *per capita* consumption nearly 20 years ago. Even now four times as much is consumed as is grown each year, and only one fifth of the forest land is set apart definitely for timber

[1] From the address of Dr. Charles D. Walcott, the retiring president of the American Association for the Advancement of Science, Washington, D. C., December 29, 1924.



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production. In spite of the growing shortage of timber and the mounting costs of bringing it from remote regions, scores of millions of acres of once productive forest land are lying idle, and we are still wasting two thirds of all the wood that is cut.

The story of our wild life and our waters is little different. Birds, fish, shell-fish, fur bearers, game animals, all have reached an alarming stage of depletion as a result of destructive exploitation. Streams, lakes and coastal waters have been polluted. Many of the streams and lakes which could afford a perpetual source of food, power, irrigation water, recreation, water for drinking, sanitation and other domestic uses, as well as channels for cheap transportation, have been reduced in flow or filled with sediment, following forest destruction or unwise cultivation or pasturing on their watersheds.

All these are renewable resources. With wise use none of them need have been depleted, and most of them can be made even more productive than they have been in the past. Few would go so far as to contend that such replenishment is unnecessary or undesirable. Many, however, consider it impossible, and even assert that major reductions of the waste in utilizing existing resources are impracticable. The reasons are said to be economic: more intensive farming will not pay, reforestation is too slow and costly, there are no profits in utilizing waste materials.

Yet economic impracticability is frequently only a longer name for ignorance. The discovery of new principles or new methods may make it economically practicable to intensify farming. Better understanding of silvicultural principles and closer study of the life history of our forests will show us how to utilize that resource without jeopardizing its continued productivity, and without increasing the economic burden on the users. Thorough technical knowledge of the product, whether farm crops, timber or what not, will enable us to utilize profitably a great deal that is now wasted.

Our mineral resources, as a general proposition, can not be renewed through human effort, at least in the present state of knowledge. But even with them, the available supplies can be extended almost indefinitely through the discovery of new methods of extraction, or through the discovery and utilization of substitute materials.

To obtain the results desired it is evident that the great masses of humanity have yet to be educated in the scientific method of thought and action, not only in darkest Africa, but here in the United States and in all countries. This is the greatest task immediately before us. All scientific men and women may do their bit—*first,* by training themselves to observe accurately, to think straight and then to record clearly and honestly, and to draw warranted conclusions based on the facts presented, "free from previous preconception and prejudice"; *second,* by reviewing the mass of technical information with which they are familiar and telling the story they have learned in simple, clear language, free from obscure, complicated, technical and verbose wording. These simple suggestions apply not only to research workers in science, but to all the professional classes as well, theologians, doctors, lawyers, statesmen—especially lawyers and politicians, and of course professional teachers in schools and colleges.

That the scientist should have the virtues of charity, tolerance, broad-mindedness, patience, persistence and a very high regard for his fellow man is absolutely essential if he is to reach the heights and be of the greatest service. Agassiz and Pasteur were great scientists and great souls, and gave service by teaching as well as by their example of living on a high plane of thought and action. Some other men have been brilliant

contributors to knowledge, although their general manner of living may have been an injury rather than a service to mankind. We need to be grateful for the constructive service of each life, and our criticism of those who have passed and of those who are still active needs to have a broad friendliness as its basis. I believe, too, that a good scientist should be a good Christian, and a good Christian should be a good scientist in his method and work, as both are seeking the truth and the fundamental principles underlying their respective fields of endeavor.

Besides the necessity for each individual to train and conquer himself and to exercise such influence as may be possible on those within his immediate environment, there is great need for him to engage in cooperative public work, by associating with others of similar aspirations, and bringing legitimate influence to bear on all agencies that are concerned in any way with the educational system of the people, from the kindergarten to the university, from the leaflet of the advertising promoter to the great newspapers, magazines and books that make up the thousand and one publications of our day. His influence must also be brought to bear upon the important visual agencies of the motion-picture screen and every other form of illustration, as well as on all those agencies that are seeking to develop "the consciences, the ideals and the aspirations of mankind." The scientific method must be applied to all these factors if we have faith in its ideals.

Is it not practicable for the association to organize a progressive, live committee of men and women to deal with the popularizing of scientific knowledge? It might arrange special sessions for the public to which the layman could go with the feeling that they were for his entertainment and his instruction and not solely to arouse the interest of specialists in their particular field of research. Of all human beings, the child is the greatest and most active investigator of all that pertains to his environment. Why not provide for a junior section of the American Association, and last and in some respects the most important, a woman's section and sessions, at which all the scientific problems of peculiar interest to woman could be considered? We have a strong nucleus of women members, but they should be one of the great influences within the association for developing and carrying forward its work. Then there is the much discussed business man, who has a more or less hazy conception of science and scientific method, depending on whether he considers it affects his interest for good or evil. He would be a better business man, a better citizen and more successful in all his relations in life if he had a working knowledge of scientific method and principles at his command.

Every member of our association should work individually and collectively according to his or her opportunity and ability in supporting the scientific method and in insisting that, in all education of every kind and degree and for all classes, the purpose is to develop without prejudice or preconception of any kind a knowledge of the facts, the laws and the processes of nature in all natural and human relations. The natural weakness and incompleteness of all things of human origin will frequently baffle, mislead and confuse, and may even apparently bring temporary defeat, but in the long run there is no other way to eradicate sciosophy, advance the physical, mental and moral welfare of the race and justify our existence and opportunities for service as sentient human beings.

The Pilgrim fathers knew little of science, but they brought the great principles of law, truth, freedom and faith in God to America. Are we doing all in our power to perpetuate and develop them in connection with the multiplex activities of the world of to-day?